Upper Colorado River Endangered Fish Recovery Program

GREEN RIVER SUBBASIN

Floodplain Management Plan

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GREEN RIVER SUBBASIN
FLOODPLAIN MANAGEMENT PLAN

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Final

Upper Colorado River Endangered Fish Recovery Program
Project No. C-6

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EXECUTIVE SUMMARY

The Upper Colorado River Endangered Fish Recovery Program (Recovery Program) developed this Floodplain Management Plan (Plan) to provide restoration and management strategies for existing floodplain sites within the Green River Subbasin that have been acquired and/or are managed by the Recovery Program for the benefit of the endangered razorback sucker (*Xyrauchen texanus*). The goal of this Plan is to provide adequate floodplain habitats for all life stages of razorback sucker, particularly to serve as nursery areas for larvae and juveniles, for establishment and maintenance of a self-sustaining population. The objectives of this Plan are to: (1) inventory floodplain habitats; (2) identify and acquire available floodplain easements; (3) restore and manage available floodplains to benefit razorback sucker and bonytail; and (4) evaluate the effectiveness of restoration. It is hypothesized from scientific studies and hatchery culture that two other endangered fish species, bonytail (*Gila elegans*) and Colorado pikeminnow (*Ptychocheilus lucius*), will also benefit from a greater availability of floodplain habitat.

The focus of this Plan is the 107-mile reach of the middle Green River from Split Mountain to Desolation Canyon. Historic data indicate that this reach was the population center for razorback sucker in the Green River Subbasin. This reach has the only known spawning bar for razorback sucker in the Upper Colorado River Basin; suitable ecological conditions for species recovery; sufficient numbers and acreage of available floodplains; and Green River flow recommendations to ensure floodplain inundation and long-term protection of these habitats.

Inventories show that there are 37 potential floodplain sites for a total of about 11,400 acres in the Split Mountain to Desolation Canyon reach. At 18,600 cfs, the estimated area of floodplain inundation is 6,000 acres. Under average hydrologic conditions (i.e., 30–70% peak exceedence), the Green River flow recommendations predict that 18,600 cfs should occur in 1 of 2 years and be maintained for at least 2 weeks in 1 of 4 average years. This Plan identifies 16 floodplain sites totaling 4,448 acres with access by the Recovery Program for restoration and management. The Recovery Program has restored and is evaluating and managing five sites (489 acres) as long-term floodplain depressions: (1) Bonanza Bridge, 28 acres; (2) The Stirrup, 28 acres; (3) Baeser Bend, 47 acres; (4) Above-Brennan, 50 acres; and (5) Old Charlie Wash–Main, 336 acres. Long-term floodplain depressions become inundated at spring runoff and entrain larval razorback sucker, then maintain suitable water quantity and quality for 24 months, at which time the fish escape to recruit as adults in the mainstem. These floodplains reset periodically by desiccating and killing stranded predaceous and competitive nonnative fishes. Shallow depressions desiccate after a short time period, and terraces fill and drain with river stage; neither feature is suitable as nursery or rearing habitat. There are several hundred acres of terrace or small depression floodplains that form in this reach at 18,600 cfs to which the Recovery Program does not have access but may serve as nursery habitat for razorback sucker.

These areas are either under private ownership unwilling to allow easement access or are small depressions and pockets that collectively constitute a large area. These floodplains are considered a buffer to estimated fish production and recruitment.

This Plan will be implemented in three phases. Phase I prioritizes two additional floodplain sites for restoration and management that can provide an additional 900 acres of floodplain depressions for a total of 1,389 acres available at seven sites located 5–60 miles downstream of the razorback sucker spawning bar. These sites include: (1) Thunder Ranch, 330 acres, and (2) Stewart Lake, 570 acres. An easement agreement to access, flood, and manage the Thunder Ranch floodplain was acquired by the Recovery Program in 2003, and levee breaches are identified as restoration under this Plan. Stewart Lake is managed by the Utah Division of Wildlife Resources (UDWR) as the principal feature of the Stewart Lake Waterfowl Management Area. This Plan calls for cooperative and coordinated management of Stewart Lake as a nursery and rearing area to benefit razorback sucker consistent with the primary purpose of the management area.

Phase II of this Plan identifies two floodplain sites in the Ouray National Wildlife Refuge (ONWR) as additional restoration sites: (1) Leota Ponds, 1,016 acres, and (2) Johnson Bottom, 146 acres, for a total of 1,162 acres. Some restoration has taken place at Johnson Bottom and Leota Ponds, including levee breaches and installation of water control gates and fish kettles by the Recovery Program, and removal or breaches of internal dikes by ONWR. The need for additional restoration of these sites will be determined following restoration and evaluation of Thunder Ranch and Stewart Lake and response by the razorback sucker and bonytail populations to all floodplain management actions. If a need for additional restoration is identified, the Recovery Program will establish a partnership with the ONWR to develop restoration and management strategies compatible with program and refuge goals and objectives. Restoration of the two sites on the ONWR would result in an additional 1,162 acres of floodplain depressions, for a total of 2,551 acres (i.e., 1,389 + 1,162) in 9 sites located 5–60 miles downstream from the known razorback sucker spawning bar.

Phase III involves restoration of five sites, including (1) Sheppard Bottom, 300 acres, (2) Wyasket Lake, 850 acres, (3) Sportsman's Lake, 132 acres, (4) Horseshoe Bend, 22 acres, and (5) Old Charlie–Diked, 81 acres, for a total of 1,385 acres. Restoration of these floodplain sites would result in a total of 3,936 acres. These sites will require substantial mechanical excavation of floodplain basins for costs that may be substantial, but have not been computed. Sportsman's Lake is under private ownership and would require purchase of a property easement as well as structural modification to the inlet and levees, and possible excavation of an outlet. These actions could be expensive and may not be necessary if other floodplain sites are suitable for species recovery.

A mathematical Floodplain Model estimates that an average of 2,032 acres of floodplain depressions are necessary as nursery and rearing habitat to support a self-sustaining population of

5,800 adult razorback sucker with average annual recruitment of 30% (i.e., 1,740 adults; recovery target). This average is based on simulations that range from 206 to 8,131 acres with nine combinations of low, moderate, and high fish density and growth rate. Past and proposed restoration of seven sites (Phase I) will result in 1,389 acres of long-term floodplain depressions, and additional restoration (Phase II) will result in 9 sites and 2,551 acres. The restoration described in this Plan through Phase II meets the requirement for long-term floodplain depression habitat estimated by the Floodplain Model.

A timeline is not provided for this Plan because implementation of phases will depend on a number of factors, including effectiveness of levee breaches, suitable river flow conditions, response by the target fish species, the outcome of management actions, and available funding. Estimated costs are also not provided because actual costs of restoration at key floodplains are not currently known, and available funding is not known.

ACKNOWLEDGMENTS

Development of this Floodplain Management Plan was funded by the Upper Colorado River Endangered Fish Recovery Program (Recovery Program). The Recovery Program is a cooperative partnership of the U.S. Fish and Wildlife Service; Bureau of Reclamation; Western Area Power Administration; the states of Colorado, Utah, and Wyoming; Upper Colorado River Basin water users; environmental organizations; National Park Service; and the Colorado River Energy Distributors Association.

Thanks to Robert Muth, Recovery Program Director, as well as the Biology Committee, for their input into development of this Plan. Thanks also to the Green River Team, including Kevin Christopherson, Frank Pfiefer, Tim Modde, and Ron Brunson. Special thanks to John Hayse of Argonne National Laboratory for his assistance in development of the Drift Submodel of the Floodplain Model, which provided valuable insight into development of this Plan.

The Recovery Program thanks Ouray National Wildlife Refuge and the Bureau of Land Management for permission to access and manage floodplains within their jurisdiction, and for their good faith coordination in working toward the success of the Habitat Restoration element of the program and the ultimate recovery of the endangered fishes of the Upper Colorado River Basin.

1.0 INTRODUCTION

1.1 Background

The Upper Colorado River Endangered Fish Recovery Program (Recovery Program) is a cooperative partnership involving public and private interests dedicated to recovering endangered fishes in the Upper Colorado River Basin, while water development proceeds in compliance with Federal and State laws (U.S. Department of the Interior 1987). The Recovery Program is coordinated by the U.S. Fish and Wildlife Service (Service) with seven major program elements to recover the endangered Colorado pikeminnow (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), humpback chub (*Gila cypha*), and bonytail (*Gila elegans*). One of the seven major program elements is Habitat Restoration. A principal aspect of this element is floodplain restoration with the goal *"...to improve and maintain sufficient habitat to support the endangered fish species; and to apply habitat development and enhancement techniques experimentally to determine if the rare fishes will use developed habitat and if such techniques contribute to recovery"* (Nelson and Soker 2002).

Floodplains are important nursery and rearing habitats for razorback sucker (Bestgen 1990) and possibly for bonytail (Mueller 2003); Colorado pikeminnow also use warmed floodplains during high spring flows for feeding and gonadal maturation (Modde and Irving 1998; Modde 1996). The availability of floodplains in the upper basin has been reduced by flow regulation and concomitant geomorphic changes in the river channel. The need to restore these floodplain habitats has been identified as important to recovery of these endangered fishes (Tyus and Karp 1990; Modde et al. 1996). Habitat Restoration is coordinated by the Recovery Program and includes acquisition, restoration, and maintenance of floodplain habitats in the upper basin. A Draft Floodplain Habitat Synthesis Report (Nelson and Soker 2002) provides an assimilation of acquisition and restoration efforts, as well as results of related studies.

1.2 Goals And Objectives

The goal of this Floodplain Management Plan (Plan) is to provide adequate floodplain habitats for all life stages of razorback sucker, particularly to serve as nursery areas for larvae and juveniles, for establishment and maintenance of a self-sustaining population. It is hypothesized from scientific studies and hatchery culture that bonytail will also benefit from a greater availability of floodplain habitat. The objectives of this Plan are to:

1. Inventory floodplain habitats;
2. Identify floodplains necessary for species restoration;
3. Restore and manage floodplains to benefit razorback sucker and bonytail; and
4. Evaluate effectiveness of restoration.

Floodplain management plans were developed concurrently for the Green River Subbasin and the Upper Colorado River Subbasin to provide restoration and management strategies for existing floodplain sites within each subbasin that have been acquired and/or are managed by the Recovery Program for the benefit of endangered fishes. These plans are necessary for the Recovery Program to establish goals, identify management actions, and to gage progress on habitat restoration and protection. Implementation of these management plans will be the means by which the Recovery Program achieves floodplain-related recovery criteria and management actions identified in the Razorback Sucker Recovery Goals (U.S. Fish and Wildlife Service 2002a) and Bonytail Recovery Goals (U.S. Fish and Wildlife Service 2002b).

1.3 Relationship To Recovery

Final recovery goals for the razorback sucker and bonytail were approved and signed on August 1, 2002 (U.S. Fish and Wildlife Service 2002a, 2002b), and issued as a Notice of Availability on August 28, 2002 (67 FR 55270–55271). These recovery goals are consistent with requirements of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et. seq.*), and contain site-specific management actions; objective, measurable criteria; and estimates of time and costs for conservation of the species. The following site-specific management actions and tasks were identified in the Razorback Sucker Recovery Goals with respect to floodplain habitats:

> *"Management Action A-5.—Provide floodplain habitats for all life stages of razorback sucker, particularly to serve as nursery areas for larvae and juveniles.*
>
> > *Task A-5.1.—Identify appropriate bottomland sites and assess opportunities for land acquisition or easements.*
> >
> > *Task A-5.2.—Acquire or procure easements (as determined under Task A-5.1) for bottomland sites where determined necessary and feasible."*

Objective, measurable criteria were also identified in the recovery goals for the five listing factors under Section 4(a)(1) of the ESA, and were stated as the following recovery factor criteria for downlisting and delisting with respect to floodplain habitats for razorback sucker:

> *"Factor A.—Adequate habitat and range for recovered populations provided."*
>
> For Downlisting: *"7. Appropriate bottomland sites identified and opportunities for land acquisition or easements assessed (Task A-5.1)."*
>
> For Delisting: *"7. Bottomland sites acquired or easements procured (Task A-5.2)."*

2.0 PLANNING AND DEVELOPMENT

2.1 Planning

The Recovery Program was initiated under a 15-year Cooperative Agreement dated September 29, 1987 (U.S. Department of the Interior 1987; Wydoski and Hamill 1991; Evans 1993). The program functions under the general principles of adaptive management and consists of seven program elements (Box 1). In 1992, the Recovery Program initiated an inventory of upper basin bottomlands (i.e., floodplains) to guide acquisition and restoration activities under the Habitat Restoration element (Irving and Burdick 1995). Capital funds became available through the Bureau of Reclamation (Reclamation) beginning in 1993 for floodplain restoration. A Fiscal Year (FY) '93 proposal for a Habitat Enhancement Implementation Program was submitted by Reclamation for $230,000 (Johnston 1992). The proposal was revised and renamed for FY'94 as the Habitat Enhancement Project – Flooded Bottomlands, and was submitted for $1,046,000 (Nelson and Soker 2002). Total out-of-year costs in that proposal were projected at $9,920,000 through 2003, the year the Recovery Program was scheduled to end. Project activities included acquisition of property easements for management by the Recovery Program and redesign and construction of floodplains to enhance fish habitat. On October 30, 2000, Public Law 106–392 was signed by Congress authorizing up to $46 million of congressional appropriations for the Upper Colorado River Endangered Fish Recovery Program and the San Juan River Basin Recovery Implementation Program. This legislation extended the Recovery Program through 2011, but did not specifically allocate capital construction funds for the Habitat Enhancement Project.

Elements of the Recovery Program

1. Instream Flow Protection;
2. Habitat Restoration;
3. Reduction of Nonnative Fish and Sportfishing Impacts;
4. Propagation and Genetics Management;
5. Research, Monitoring, and Data Management;
6. Information and Education; and
7. Program Management.

From 1992 through 2002, the Recovery Program inventoried floodplains in the Upper Colorado River Basin (Irving and Burdick 1995; Irving and Day 1996; Bell [undated]; Bell et al. 1998; Cluer and Hammack 1999). Available floodplain sites were identified and by November, 2002, easements for access and restoration by the Recovery Program were acquired on 13 private property sites in the upper basin totaling 1,087.2 acres of land at a cost of $2,117,400 (Nelson and Soker 2002). These included five easements on three floodplain sites in the Green River Subbasin for a total of 553 acres at a cost of $191,850. An additional easement on 455.1 acres of land (about 330 acres of floodplain) was acquired in 2003 for Thunder Ranch in the Green River

Subbasin. The Recovery Program also identified and negotiated access to numerous floodplain sites on lands administered by State and Federal agencies.

In 1996, a Floodplain Restoration Plan was developed and implemented to remove or breach levees that separated key State and Federal floodplain sites from the main river channel to allow more frequent flooding at lower river levels (Flo Engineering 1996, 1997; Lentsch et al. 1996a; Crowl et al. 1998a). By 2001, restoration had occurred at 13 sites in the upper basin, totaling 730–1,815 acres, depending on river stage, including levee breaches at eight sites in the Green River Subbasin, totaling 274 acres at 13,000 cfs. Over a 10–year period, easements to most available key floodplain sites had been acquired, floodplain reconstruction had been initiated with ongoing evaluations, and hatchery propagation was providing fish for field studies of growth and survival and for augmentation of wild stocks (Nelson and Soker 2002). In 2002, the Habitat Enhancement Project entered a new phase of habitat restoration that changed the focus from acquisition and to evaluation, reconstruction, and management.

In January, 2003, the Biology Committee of the Recovery Program identified the need for comprehensive floodplain management plans for the Green River Subbasin and the Upper Colorado River Subbasin. The purpose for these plans was to assimilate and synthesize information from past floodplain restoration activities and to identify objectives and management actions for reaches of each subbasin, as well as for specific floodplain sites. These management plans will be used as guidance for recovery of the razorback sucker, and possibly for the bonytail.

2.2 Plan Development

This Plan was developed at two levels: (a) by priority river reaches within the Green River Subbasin, and (b) by floodplain sites. Priority reaches were determined by integrating information from the Draft Floodplain Habitat Synthesis Report (Nelson and Soker 2002), Research Priorities For Geomorphology Research (LaGory et al. 2003), and a Floodplain Model (Valdez 2004). Role in recovery, objectives, and management actions were identified for each reach. The second level of this Plan was development of objectives and management actions for specific sites that are available to, acquired by, and/or managed by the Recovery Program. Each site description includes: background, role in recovery, and objectives and management actions. Objectives and management actions may differ among sites, depending on geomorphic, hydraulic, hydrologic, chemical, and biological characteristics. Success criteria, uncertainties and risks, research needs, and contingencies are also identified for all sites.

2.3 Role Of Propagation And Augmentation Program

The success of this Plan depends heavily on implementation of the razorback sucker and bonytail propagation and augmentation program (Nesler et al. 2003), and the genetics management plan (Czapla 1999). This program and plan are vital to establishment of sufficient numbers of fish in the wild in order to identify patterns of habitat use, spawning sites, drift and entrainment of wild-produced larvae, and appropriate flow and floodplain management strategies to enhance survival and recruitment. Monitoring drift and habitat use by larval razorback sucker will provide a better understanding of the role of floodplain habitat in the life cycle of the species, as well as differences between floodplain sites with respect to entrainment of larvae and growth and survival. Initial management of selected Recovery Program sites will include stocking and evaluation of hatchery fish (excess to meeting the State stocking plans) to guide research and to supplement population augmentation efforts. Hatchery bonytail will also be released in and near floodplains to describe habitat use and assess their growth and survival.

Hatchery culture and holding facilities for razorback sucker have been established at the Ouray National Fish Hatchery, Ouray, Utah; and at the Service's Grand Junction Endangered Fish Facility, Grand Junction, Colorado. Hatchery bonytail are available from Dexter National Fish Hatchery, Roswell, New Mexico; Wahweap State Fish Hatchery, Big Water, Utah; and Mumma Native Aquatic Species Restoration Facility, Alamosa, Colorado.

2.4 Role Of Floodplain Model

A Floodplain Model (Valdez 2004) was developed for the Recovery Program to estimate the amount of floodplain habitat necessary to recover the razorback sucker and to support recovered self-sustaining populations. This mathematical model is user interactive and consists of 31 numbered steps, including 11 user-specified input variables (Box 2) and 20 automated output variables (Box 3). Output variables include computations of total acres and hectares of floodplains necessary to support specified densities of fish, number of fish recruiting to maturity at 400 mm TL, and recruitment rate as a percentage of the initial adult population.

The Floodplain Model is used in this management plan to help assess the importance of river reaches and their potential for species conservation. The model considers the relationships among the location of known and possible spawning sites and available floodplain habitats, both managed and un-managed. The model is also used to assess the importance and role of specific floodplain sites, the estimated contribution of each site to recovery, identification of critical and limiting factors, and identification of management elements necessary for gaining full benefits of given sites. The Floodplain Model estimates that 2,032 acres (823 ha) of floodplain depressions that hold fish for 24 months are needed to support a self-sustaining population of 5,800 adult razorback sucker with an average annual recruitment of 30%, at average fish growth and density.

Floodplain Model Input Variables

- Initial population size,
- Sex ratio,
- Average total length (TL) of females,
- Percent hatching success,
- Percent larval emergence,
- Survival rate of larvae per mile
- Time in floodplains,
- Survival in floodplains,
- Fish growth rate,
- Fish density, and
- Annual survival in mainstem.

2.5 Coordination

Floodplain Model Output Variables

- Number of females from adults, sex ratio,
- Average female fish weight,
- Number of eggs produced,
- Number of larvae emerging,
- Percent of larvae entrained,
- Number of larvae entrained,
- Number of fish surviving in floodplains,
- Average total length,
- Average weight,
- Biomass of fish surviving,
- Computed area of floodplains in acres,
- Computed area of floodplains in hectares,
- Number of fish escaping to the mainstem,
- Total length of fish escaping,
- Number recruited as adults (400 mm TL),
- Growth in mm to reach 400 mm TL,
- Months required to reach 400 mm TL,
- Total months for fish to recruit,
- Number recruited, and
- Percent recruitment.

This Plan was developed under the authority and support of the Upper Colorado River Endangered Fish Recovery Program. Recovery Program partners include: Colorado River Energy Distributors Association, Colorado Water Congress, Land and Water Fund of the Rockies, National Park Service, State of Colorado, State of Utah, State of Wyoming, The Nature Conservancy, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, Utah Water Users Association, Western Area Power Administration, and Wyoming Water Association.

An interdisciplinary team was established for the Green River Subbasin to provide input for development of this Plan. The team was comprised of core principal investigators, biologists, and managers involved in floodplain habitat activities in the Green River Subbasin representing the Service and Utah Division of Wildlife Resources (UDWR). This team was established to work with the Principal Investigator for this Plan, the Habitat Restoration Coordinator, and the Recovery Program Director's office to: (a) identify important river reaches, (b) identify important floodplain sites, (c) describe past and ongoing floodplain investigations, and (d) identify successful and unsuccessful management strategies. A workshop with the Green River Team was held April 24, 2003, and individual team members were contacted for information throughout the development of this Plan. A workshop is planned between the Recovery Program and the Ouray National Wildlife Refuge to coordinate future floodplain restoration efforts on the refuge. Development and implementation of this Plan was also coordinated with the Bureau of Reclamation, Upper Colorado Region.

3.0 SCIENTIFIC BASIS AND UNDERLYING PRINCIPLES

3.1 Scientific Basis For Plan

This Plan is based on scientific principles derived from research on floodplains throughout the Colorado River Basin, as well as from other systems. The fundamental basis of this Plan is that floodplains provide nursery habitat for razorback sucker, and restoration and appropriate management of these floodplains will assist the recovery of this and other endangered fish species. Floodplains develop along rivers with valley floors that are extensively covered with alluvium and/or sand. The river flowing through this substrate carves an active channel that is flanked by low relief bottomlands that may have groundwater connection with the river and/or become inundated during high-flow periods. High-flow periods of most western rivers are usually associated with snow-melt runoff in spring (Poff et al. 1997). The timing and frequency of flooding, magnitude of flows, and duration of peak flows determine the degree of floodplain connection to the river. Considerable scientific research has been conducted to better understand the complex inter-relationships associated with formation, inundation, maintenance, and desiccation of riverine floodplains (Ward 1989).

Flow regulation can disrupt hydrological and ecological connectivity between the river channel and alluvial floodplains (Ward and Stanford 1995). Reduction in spring peaks can reduce connectivity and lead to geomorphic channel changes and vegetative encroachment that may exacerbate this disconnection (Andrews 1986; Graf 1978). Floodplain reconnection is vital to restoring some of the structure and function of floodplains disrupted by flow regulation (Stanford et al. 1996).

Flow of the middle Green River is largely regulated by Flaming Gorge Dam. This flow regulation has reduced the frequency of connection of the river to floodplains, as well as the duration of connection (Stanford 1994), and is believed to be a major factor in the endangerment of the razorback sucker (Tyus and Karp 1990; Modde 1996, 1997). Tributary inflow, especially from the Yampa River, can periodically affect flows of the middle Green River during spring snow-melt runoff or from late-summer monsoonal rain storms. The relationship of flow regulation and floodplain inundation in the middle Green River is sufficiently understood to predict numbers, acreage, and types of floodplains at given river stages, but individual floodplain dynamics are not well understood; e.g., flow and particle entrainment rates, sedimentation, water retention. These inter-relationships are often confounded by physical, chemical, and biological attributes and linkages that are unique to each floodplain site (Flo Engineering 1997; Crowl et al. 1998b). Given this complexity and dynamic character of floodplains and river flows, predictions in floodplain formation and maintenance, as well as management plans for these floodplains, must be considered provisional and subject to ongoing modification with new information from scientific findings.

3.2 Underlying Principles Of Plan

This Plan is based on five underlying principles:

1. Structure and function of the Green River ecosystem are sufficiently intact to support wild self-sustaining populations of razorback sucker and bonytail;
2. Floodplain restoration and flow re-regulation will enhance endangered fish habitats;
3. Flow recommendations for the Green River will be evaluated through National Environmental Policy Act (NEPA) compliance and implemented accordingly;
4. Wild populations of razorback sucker and bonytail must be initiated from hatchery stocks and through habitat restoration to better understand specific life history needs in the wild, including nursery and rearing habitats;
5. Young fish remaining in floodplain depressions for 2 years exhibit the best growth and survival before recruiting to mainstem populations; and
6. Best management strategy is based on the "reset theory" of inundating floodplains for 2−3 years to enhance growth and survival of razorback sucker and bonytail, and allowing floodplains to become desiccated to periodically kill nonnative fish.

The first and second principles state that the Green River Subbasin retains many of its natural ecological aspects and that floodplain restoration, combined with flow re-regulation, can maintain the structure and function of these habitats to assist recovery of razorback sucker and possibly bonytail. Although much of the Upper Colorado River Basin is flow-regulated, much of the original structure and function of the ecosystem is intact. The upper basin supports the only remaining wild self-sustaining populations of Colorado pikeminnow and five of the six known wild self-sustaining populations of humpback chub. The upper basin also supports viable self-sustaining populations of the four other native, non-endangered fish species: flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), roundtail chub (*Gila robusta*), and speckled dace (*Rhinichthys osculus*). This naturalized system provides the opportunity for recovery of razorback sucker through habitat restoration and flow regulation with the minimum necessary investment of resources. The estimated time to achieve recovery of the razorback sucker is 22 years (U.S. Fish and Wildlife Service 2002a), and is based on the assumption that self-sustaining populations can be established in the first 14 years.

The third principle assumes that flow recommendations for the Green River (Muth et al. 2000) will be evaluated through NEPA and ESA compliance and implemented accordingly. Flows provided through this compliance process will insure inundation of floodplains on a regular basis. The fourth principle is that wild populations of razorback sucker must be initiated from hatchery stocks and habitat restoration to better understand specific life history needs, including habitat requirements. Floodplain restoration activities will be conducted simultaneous to releases of hatchery fish in order to better understand life history needs based on fish habitat use and response. Larval entrainment, growth, and survival in floodplains can be confirmed from wild, free-roaming fish.

The fifth and sixth principles are based on the "reset theory" of floodplain management, which allows floodplains to inundate and remain flooded for at least 2 years, then desiccate. This "reset theory" serves the fundamental ecological functions of providing connectivity for fish entrainment and movement, stimulated floodplain production, and periodic desiccation to reduce effects on nonnative fishes. This "reset theory" has not been thoroughly tested, but research on various components of the strategy indicate a high probability of success.

Ecological functions of "reset theory"

1. Periodic inundation allows access to drifting larval razorback sucker and escapement of adults,
2. Periodic inundation/desiccation stimulates food production and freshens water quality, and
3. Periodic desiccation strands and kills nonnative fishes

3.3 Green River Flow Recommendations

Flow recommendations for the Green River downstream of Flaming Gorge Dam (Muth et al. 2000) are designed to be implemented, evaluated, and revised according to findings of scientific investigations and through NEPA and ESA compliance. Flow recommendations are made for summer through winter base flows and for spring peaks for each of three longitudinal river reaches, and are based on five hydrologic conditions that reflect annual river volume (Table 3-1). The basis for the general recommendation is that peak flows should be of the magnitude, timing, and duration to provide floodplain inundation in the Ouray reach for at least 2 weeks in 4 of 10 years and at least bankfull flows in 1 of 2 years. Under average hydrologic conditions (30–70% peak exceedence), 18,600 cfs (527 m^3/s) should occur in 1 of 2 years and be maintained for at least 2 weeks in 1 of 4 average years. Average peak flow of the Green River near Jensen (RM 316), 56 years of record through 2000 (pre- and post-Flaming Gorge), is 19,706 cfs; this is the instantaneous peak and does not reflect duration.

Area of floodplain inundation for different river flows was determined for portions of the middle Green River using a HEC-2 step backwater model (Flo Engineering 1996). This model determined that for existing conditions (without levees removed) in the Ouray reach (River Mile [RM] 252–265), the area of floodplain inundation increases rapidly at flows exceeding about 18,600 cfs (Figure 3-1). With existing levees removed, flooding in the Ouray reach would be initiated at 13,000–16,000 cfs resulting in about 5,400 acres of floodplains. Similar relationships were found from aerial photography for existing conditions from Pariette Wash to Split Mountain (Bell et al. 1998). The majority of these floodplains are terraces that fill and drain with river stage and may not hold water and fish for long time periods and therefore, may not currently be suitable nurseries for razorback sucker.

Relationship of flow to floodplain area from Pariette Wash to Splt Mountain (240–319; Bell et al. 1998)

- 5,904 acres at 20,000 cfs
- 9,550 acres at 22,000 cfs
- 13,927 acres at 25,000 cfs

Table 3-1. Recommendations for spring peak flows by hydrologic condition for Reach 2 (Yampa River to White River) to benefit endangered fishes in the Green River downstream of Flaming Gorge Dam (excerpted from Muth et al. 2000).

Criteria	Hydrologic Condition				
	Wet (0 to 10% Exceedence)	Moderately Wet (10 to 30% Exceedence)	Average (30 to 70% Exceedence)	Moderately Dry (70 to 90% Exceedence)	Dry (90 to 100% Exceedence)
General recommendation	Peak flows in Reach 2 should be of the magnitude, timing, and duration to provide floodplain inundation in the Ouray portion of the river for at least 2 weeks in 4 of 10 years and at least bankfull flows in 1 of 2 years. In all years, peak flows should be of sufficient magnitude and duration to provide at least some in-channel habitat maintenance throughout the reach. No upper limits are placed on recommended peak flows in any hydrologic condition. The duration of peak flows less than 527 m^3/s (18,600 cfs) should be limited, because neither floodplain nor backwater habitats are available at these flows.				
Peak-flow magnitude	≥748 m^3/s (26,400 cfs)	≥575 m^3/s (20,300 cfs)	≥527 m^3/s (18,600 cfs) in 1 of 2 average years; ≥235 m^3/s (8,300 cfs) in other average years	≥235 m^3/s (8,300 cfs)	
Peak-flow duration	Flows greater than 643 m^3/s (22,700 cfs) should be maintained for 2 weeks or more, and flows greater than 527 m^3/s (18,600 cfs) for 4 weeks or more.	Flows greater than 527 m^3/s (18,600 cfs) should be maintained for 2 weeks or more.	527 m^3/s (18,600 cfs) should be maintained for at least 2 weeks in at least 1 of 4 average years.	Flows greater than 235 m^3/s (8,300 cfs) should be maintained for at least 1 week.	Flows greater than 235 m^3/s (8,300 cfs) should be maintained for 2 days or more except in extremely dry years (≥98% exceedence).
Peak-flow timing	Peak flows should coincide with peak and immediate post-peak spring flows in the Yampa River.				

Table 3-1. Continued

Anticipated effects	Significant inundation of floodplain habitat and off-channel habitats (e.g., tributary mouths and side channels) to establish river-floodplain connections and provid warm, food-rich environments for growth and conditioning of razorback suckers (especially young) and Colorado pikeminnow.	Significant inundation of floodplain habitat and off-channel habitat in at least 1 of 4 average years; some flooding of off-channel habitats in all years.	No floodplain inundation, but some flooding of off-channel habitats. May benefit recruitment of Colorado pikeminnow in some years.
	Significant channel maintenance to rework and rebuild in-channel sediment deposits (including spawning substrates), increase habitat complexity, form in-channel sand bars, and prevent or reverse channel narrowing.	Significant channel maintenance in at least 1 of 2 average years.	Some channel maintenance in all years because flows exceed the incipient-motion threshold.
	Provide conditions for gonadal maturation and cues for spawning migrations and reproduction by the endangered fishes		

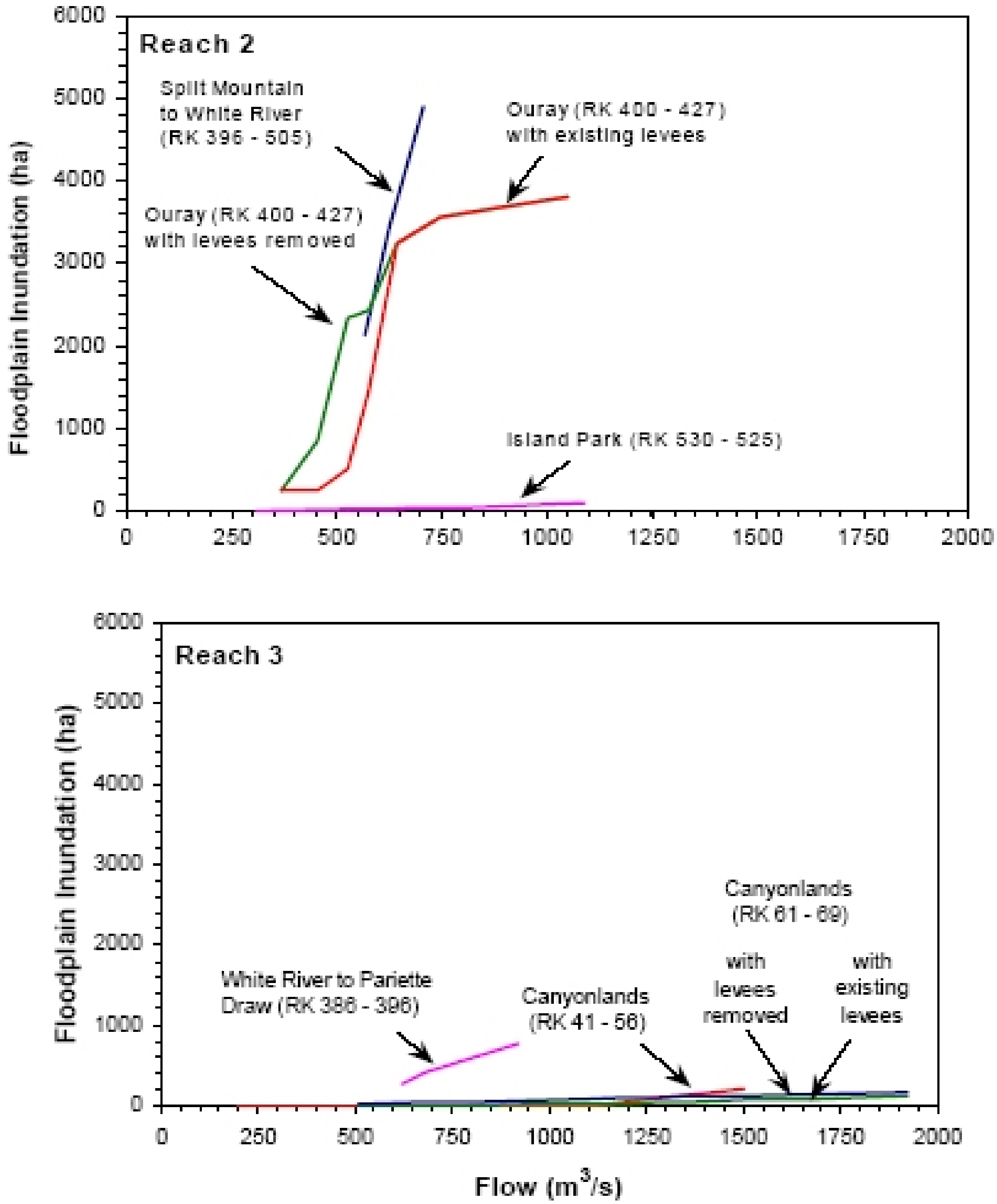


Figure 3-1. Relationships between flow and floodplain habitat inundation in Reaches 2 and 3 of the Green River. Sources: Bell et al. (1998); FLO Engineering, Inc. (1996); Cluer and Hammack (1999) (excerpted from Muth et al. 2000).

3.4 Types Of Floodplains

Floodplains in the Upper Colorado River Basin are classified as depressions, terraces, and gravel pits. Gravel pits are mechanical excavations that often function as depressions (Figure 3-2; Irving and Burdick 1995). A fundamental understanding of the hydrological and biological chronology of these floodplains is important to coincide management of these floodplains with appearance and development of the larval fish. All three features may become inundated during high spring runoff and may dry and reset in summer. The degree of inundation varies among floodplain sites, depending on the magnitude of runoff and the ground elevation that separates the feature from the main river channel. Depressions and gravel pit ponds are typically separated from the main channel by an elevated levee that is either natural or manmade. An undesirable feature of gravel pits is the often deep excavation below river bed elevation that retains water permanently and becomes a long-term refuge and source of nonnative fishes. Terraces are sloping features that fill and drain with changes in river stage. The current management strategy for depressions and gravel pit ponds is habitat restoration through either partial removal of levees or one or more breaches in a levee to allow flooding at lower river stages (Lentsch et al. 1996a; Utah Division of Wildlife Resources 1996; Flo Engineering 1997; Nelson and Soker 2002).

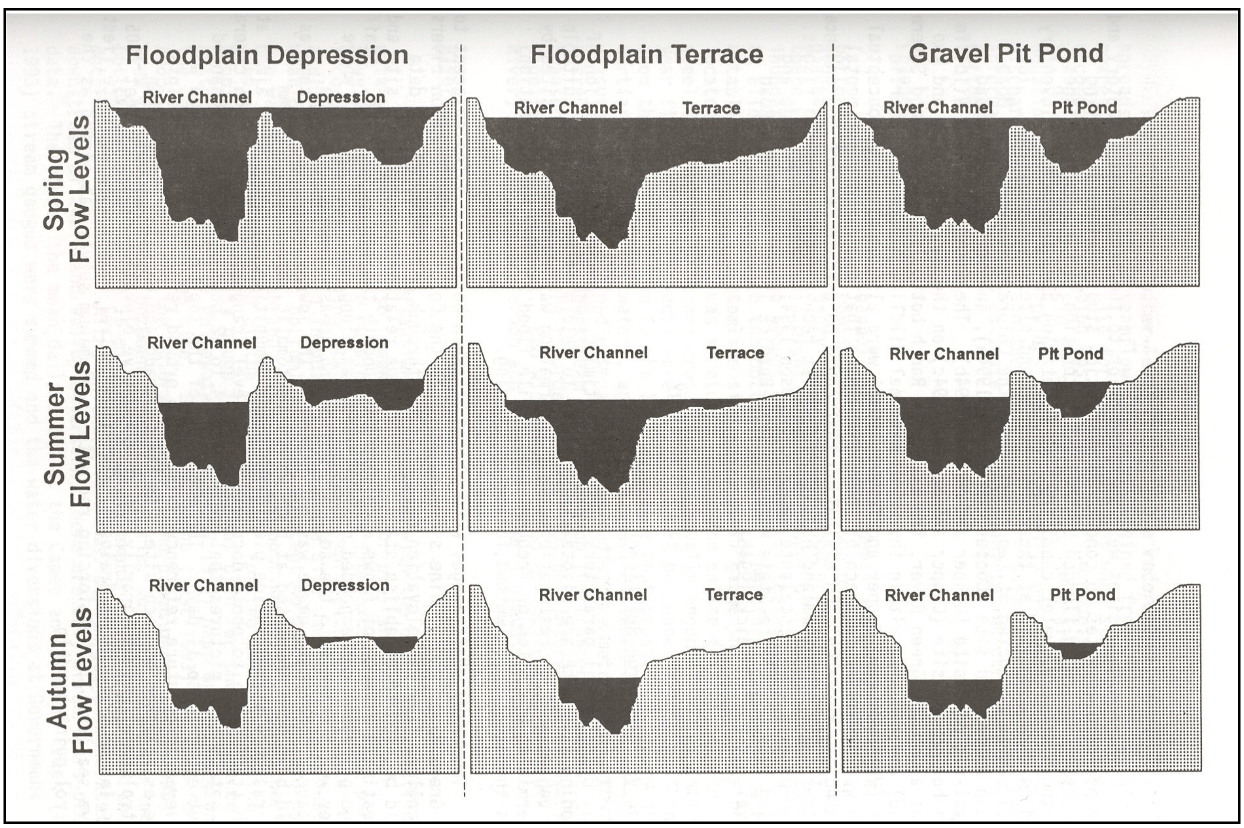


Figure 3-2. Schematic of the bed profile of the three major floodplain classifications at various flow regimes in the Upper Colorado River Basin (excerpted from Irving and Burdick 1995).

3.5 Role Of Floodplains

Floodplains are low lying areas that adjoin the active river channel and become inundated during periods of overbank flooding (Armantrout 1998), primarily during spring floods. The reproductive biology of the razorback sucker is linked to these spring flood events (Tyus 1987; Tyus and Karp 1990; Modde et al. 1995). Adults deposit and fertilize eggs over main channel cobble bars near the peak of spring runoff (Tyus 1987; Tyus and Karp 1990; Modde and Irving 1998). Spawning occurs at 16–19°C, hatching occurs in 6–7 days at 18–20°C, and larvae swim up in 12–13 days (Snyder and Muth 1990). Larvae become transported downstream by river currents at swim-up phase and are entrained in riverside floodplains when the river is still at flood stage (Osmundson and Kaeding 1989). These floodplain habitats are highly productive (Mabey and Shiozawa 1993; Modde 1997) and provide an important and timely food source for the young fish during a "critical period" when nutritional needs shift from endogenous (yolk) to exogenous (zooplankton) sources at between 8 and 19 days of age (Papoulias and Minckley 1990, 1992). Hence, it is critical for razorback sucker larvae to reach productive and sheltered habitats within 1-2 days of swim-up (Figure 3-3). Several factors determine benefits of these floodplains to razorback sucker, including timing of inundation, duration of intra-annual connection with the river, inter-annual frequency of connection, and inter- and intra-annual persistence of water quantity and quality to sustain fish. These factors are examined for each floodplain site described in this Plan, and actions are identified to maximize benefits to razorback sucker and possibly bonytail. Life history requirements of bonytail are not well known, and it is hypothesized that an increased availability of floodplains will also benefit this species.

<table>
<tr><th colspan="26">Days</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td></tr>
<tr><td colspan="7"><Eggs hatch in 6–7 days-></td><td colspan="13"><------------Larvae swim up in 12–13 days------------></td><td colspan="6"><----Larvae drift----></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="12"><-------------Larvae shift from endogenous to exogenous food source in 8-19 days-------------></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="12"><Larvae may starve without nursery habitat-></td></tr>
</table>

Figure 3-3. Chronology of egg incubation, swim-up phase, and shift to exogenous food sources for razorback sucker larvae. Larvae need a food source or may begin to starve at 8-19 days of age.

3.6 Nonnative Fish In Floodplains

Over 40 species of nonnative fish have become established in the Upper Colorado River Basin (Tyus et al. 1982). Many of these species are predators and competitors of native fishes, and nonnative species are considered a principal cause in species endangerment. One of seven Recovery Program elements is Reduction of Nonnative Fish and Sportfishing Impacts, and activities in the upper basin have been implemented and are ongoing to reduce the detrimental effects of these nonnatives. Floodplains attract large numbers of nonnative fishes and some of these species reproduce in these habitats (Modde 1997; Birchell and Christopherson 2002; Burdick 2002; Mueller 2003). The principal and most common floodplain species include a variety of cyprinids, centrarchids, and ictalurids. Nonnative fish control efforts in the upper basin have yielded variable results, and show that certain large predators (i.e., northern pike [*Esox lucius*], smallmouth bass [*Micropterus dolomieui*], channel catfish [*Ictalurus punctatus*]) can be reduced in numbers, but small forms (e.g., red shiner, fathead minnow, green sunfish, bullheads) are less affected (Upper Colorado River Endangered Fish Recovery Program 2002). The large numbers of nonnative fishes in floodplains can be logistically difficult to control without intensive long-term management and substantial ongoing financial investment , which are not consistent with the concept of population self-sustainability for recovered species. This highly-managed approach (i.e., “floodplain repatriation”) of isolation of floodplains from the river channel and mechanical or chemical removal of nonnative fishes is being used in the Lower Colorado River Basin where flows are highly regulated and habitat is extensively fragmented (Minckley et al. 2003; Mueller and Marsh 2003).

Principal nonnative fishes in floodplains

- Common carp (*Cyprinus carpio*),
- Fathead minnow (*Pimephales promelas*),
- Green sunfish (*Lepomis cyanellus*),
- Black bullhead (*Ameiurus melas*),
- Red shiner (*Cyprinella lutrensis*), and
- Largemouth bass (*Micropterus salmoides*)

The strategy of floodplain management recommended for the upper basin is based on the “reset theory”, and is different from the “floodplain repatriation” approach. Resetting floodplains allows periodic inundation and desiccation that provide timely productive habitats for native fishes and reduce numbers of nonnative forms (see section 3.7). Spring flooding allows entrainment of drifting razorback sucker larvae, escapement of older fish, and periodic desiccation serves to reset the floodplain and kill all remaining fish. Nonnative fishes can also access the floodplains during connection with the river, but initially in low numbers and primarily as adults which generally feed on prey larger than larvae. Reproduction by nonnatives occurs in late spring and summer when size of young razorback sucker exceeds that of newly-produced nonnatives, hence reducing predation effects.

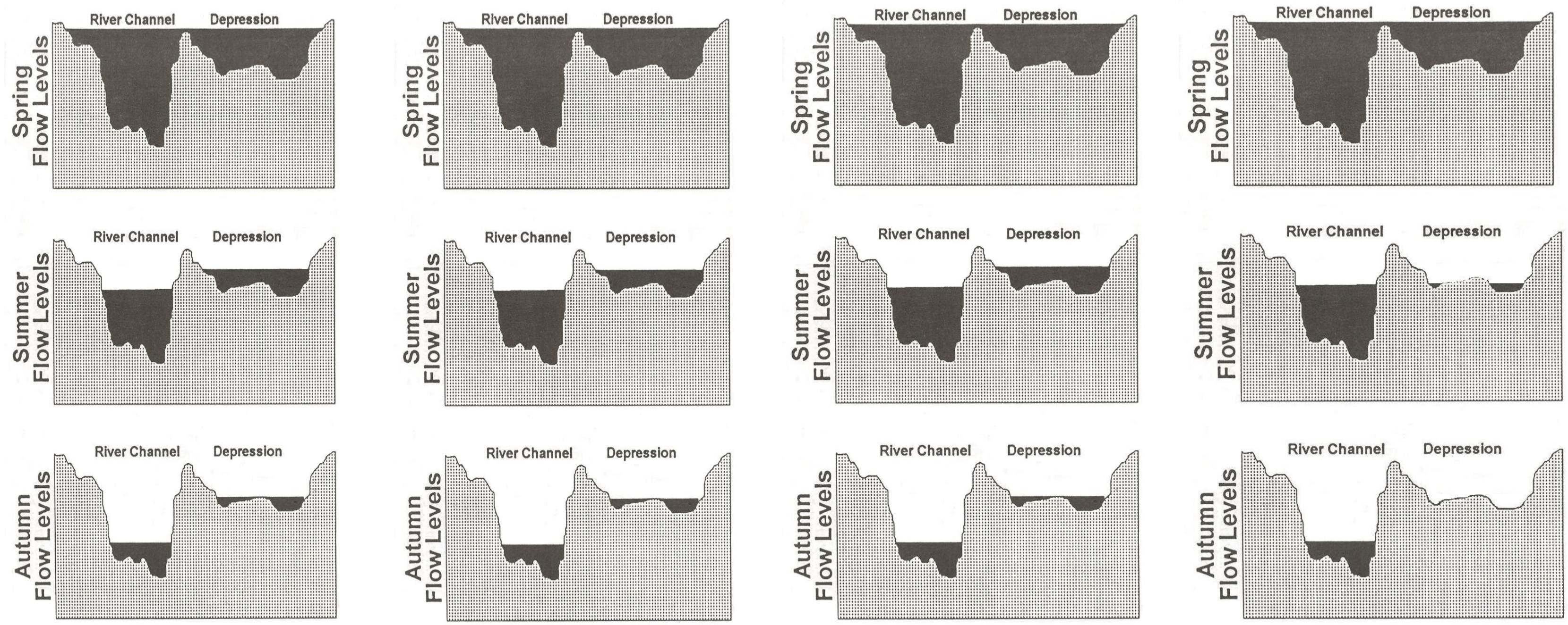
Studies of Green River floodplains indicate that razorback sucker can survive in the presence of large numbers of nonnative fishes following a year of desiccation. In October, 1995, Modde (1997) reported 28 age-0 razorback sucker (3.7 inches TL, 94 mm TL) in Old Charlie Wash in the presence of large numbers of nonnative fishes and after a dry period in 1994. In August, 1996, Modde (1997) also reported 45 age-0 razorback sucker (2.6 inches TL, 66 mm TL). Assuming that these fish entered Old Charlie Wash as larvae during runoff in the previous June, the fish captured in October, 1995, were about 4 months old, and those captured in August, 1996, were about 2 months old. The Floodplain Model predicts highest growth rate of razorback sucker at 94 mm TL in about 3.3 months, and growth to 66 mm TL in about 2.3 months. Hence, growth exhibited by these wild fish in the presence of large numbers of nonnatives was higher than or equal to highest growth rates for the species. Survival rate of these fish was not determined because the initial numbers of entrained young was not known.

A separate study tested the hypothesis that larval razorback sucker can survive in floodplain depressions following a reset year (Birchell and Christopherson 2002). Larval razorback sucker and bonytail stocked into the Stirrup floodplain in May 2002 in the presence of adult fathead minnow, red shiner, black bullhead, green sunfish, and common carp survived at rates of 1.7–1.9% for bonytail (17.1% in control) and 0.4–0.7% for razorback sucker (12.0% in control). A study to evaluate the Leota floodplain as a grow-out site assessed survival of 66,110 stocked larvae and 900 razorback sucker of various sizes during March through May 2001. A total of 84 razorback sucker were recaptured, including 35 age-0 in the presence of large numbers of nonnative fishes. Specific survival rate could not be determined because fish could have escaped during draining of this floodplain site.

3.7 Floodplain Management Strategy

The recommended management strategy for floodplains of the upper basin is based on the "reset theory" of inundation and desiccation of depressions on a 12 or 24–month cycle. The "reset theory" of floodplain management has not been implemented and tested in its entirety. Components of the strategy have been successful as described in this Plan, and uncertainties, risks, contingencies are presented in section 7.5. This strategy is illustrated in Figures 3-4 and 3-5. The success of this floodplain management strategy depends on six factors:

1. Connection of the floodplain with the river channel in year 1;
2. Entrainment of drifting larvae in year 1;
3. Sufficient food production with a chronology of development timed to arrival of larvae;
4. Suitable quantity and quality of water to support fish for 12 or 24 months;
5. Reconnection of the floodplain in year 2 or 3 to allow escapement of fish to the mainstem and for freshening of water quality in the floodplain; and
6. Periodic desiccation to reset floodplain.



YEAR 1
- First Connection
- Larval Entrainment
- River Inundation
- High Production
- Fish Length: 20–150 mm

YEAR 2
- Reconnect in Spring
- Fish Remain
- Water Refresh
- Renewed Production
- Fish Length: 150–300 mm

YEAR 3
- Reconnect in Spring
- Some Fish Escape
- Water Refresh
- Renewed Production
- Fish Length: 300–400 mm

YEAR 4
- Reconnect in Spring
- Fish Escape
- Desiccate – Reset
- No Production
- Fish Length: 400+ mm

Figure 3-4. Schematic of idealized “reset theory” of floodplain management strategy for the Green River Subbasin.

Management Action or Event	YEAR 1												YEAR 2												YEAR 3											
Year-->					0	1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3	3
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Floodplain connected; larvae become entrained					<>																															
Fish remain in floodplain through summer and over winter year 1						<------------------------------->																														
Floodplain connected; fish remain entrained																	<>																			
ESCAPE SCENARIO 1: Floodplain is drained forcing fish to leave after 16 m																			<--->																	
Fish remain in floodplain through summer and over winter year 2																			<------------------------->																	
ESCAPE SCENARIO 2: Floodplain connected; some fish leave voluntarily																													<>							
ESCAPE SCENARIO 3: Floodplain is drained forcing fish to leave after 28 m																															<--->					
Fish size at growth rate: LOW					20												100			210									312			363				
MODERATE					20												150			300									512			530				
HIGH					20												200			400									536			560				

Figure 3-5. Floodplain management strategy with three escape scenarios that assume the fish will return to the main river. Size of fish in millimeters at the end of indicated number of months is presented for low, moderate, and high growth rates.

3.7.1 Floodplain Connection

Connection of the floodplain to the river channel is critical to this management strategy. Historically, the river flooded during spring and the area of connected floodplain habitat depended on the magnitude of runoff. Flow regulation and concomitant geomorphic changes in the river channel have altered the magnitude, frequency, duration, and timing of floodplain connection and inundation. The foundation of this strategy is to enhance floodplain connection and inundation through mechanical modification (e.g., levee removal or breaches) and flow re-regulation (e.g., Green River flow recommendations; see section 3.3). Despite modification and flow re-regulation, floodplain connection will not be possible for most floodplain sites in dry years (90–100% peak exceedence) and moderately dry years (70–90% peak exceedence; Figure 3-6). Connection of key modified floodplains should occur in most average years (30–70% peak exceedence), and connection of most or all floodplains should occur in moderately wet (10–30% peak exceedence) and wet years (0–10% peak exceedence). The goal of this Plan—to provide adequate floodplain habitats for all life stages of razorback sucker—will be accomplished by modifying floodplains to inundate with flows identified in the Green River flow recommendations. It is recognized that not all floodplains will connect to the main channel in given years, or if connected may not function as desired. Hence, the greatest number of connected floodplain depressions possible will increase the likelihood of success of this strategy.

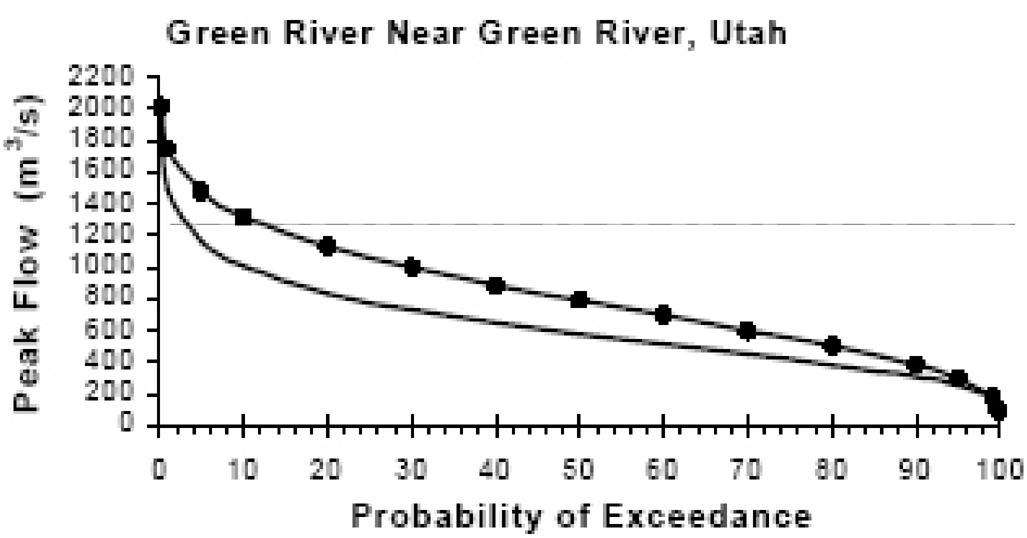


Figure 3-6. Peak flow exceedance curves for regulated (solid line) and unregulated (dotted line) flows in the Green River, near Green River, Utah, 1963–1996 (excerpted from Muth et al. 2000). Horizontal dashed line shows flow recommendation of 527 m^3/s (18,600 cfs).

3.7.2 Larval Entrainment

The proportion of drifting razorback sucker larvae entrained at floodplain sites downstream of a spawning bar has not been determined. Given that the razorback sucker is a highly fecund fish species, with average production of about 188,600 eggs per female at 550 mm TL and 1,757 g body weight, the number of larvae produced by a population of 5,800 adults with a 3:1 male to female effective sex ratio (i.e., 1,740 females) is expected to be about 5.5 million (Floodplain Model, Valdez 2004). Drifting larvae follow a pattern of downstream reduction in numbers of drifting particles described as a negative exponential decay function (Figure 3-7), which assumes ongoing mainstem mortality and periodic entrainment at floodplain sites. Eventually, numbers of drifting larvae become extinguished with distance downstream from a spawning bar. The Floodplain Model predicts that only about 1% of drifting larvae remain in the main channel 36 miles downstream of a spawning bar at a 90% mile-to-mile survival rate and 10% entrainment at five sites. Hence, downstream floodplain sites closest to a spawning bar are likely to entrain the greatest numbers of drifting larvae and provide earliest refuge for maximum growth and survival of young fish.

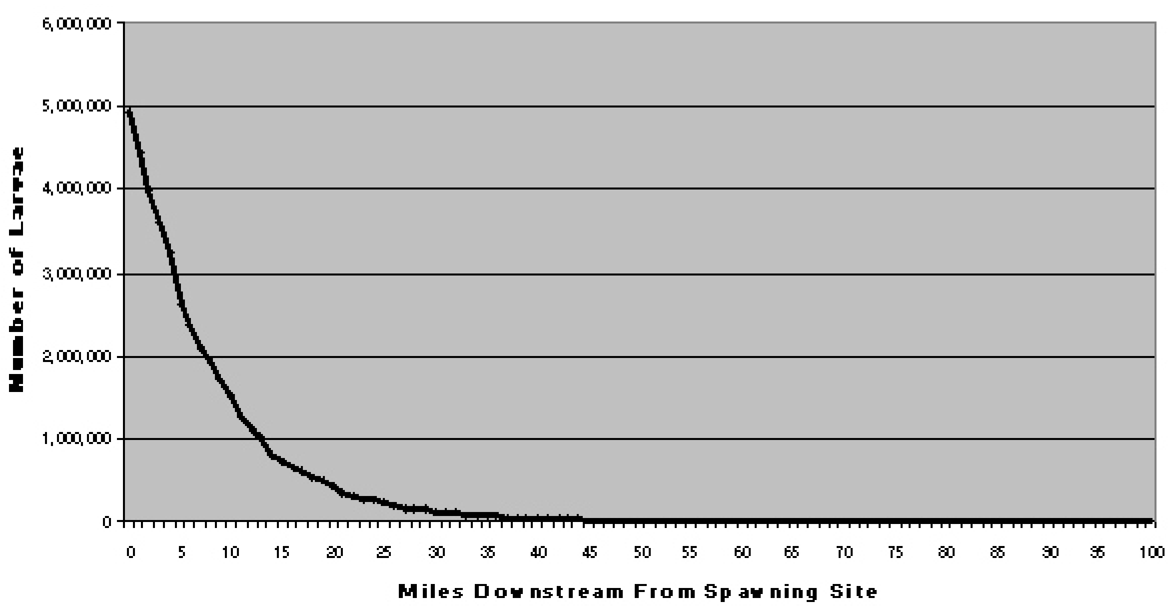


Figure 3-7. Number of larvae surviving to the next river mile as a negative exponential decay function, which assumes ongoing mainstem mortality and periodic entrainment at floodplain sites. Function generated by Floodplain Model (Valdez 2004).

The geomorphic and hydrologic characteristics of given floodplains that maximize larval entrainment are not well understood. It is assumed that drifting larvae are randomly mixed in the river water column and that those floodplains that receive the greatest water volume entrain the greatest numbers of larvae. Studies of drifting surrogate species and artificial beads indicate that these assumptions may not be correct. Numbers of drifting larvae of flannelmouth sucker and bluehead sucker in the Upper Colorado River were greater along shorelines than in the central channel (Valdez et al. 1985). Preliminary studies with artificial beads also indicate that particle distribution may not be random (Personal communication, Kevin Christopherson, Utah Division of Wildlife Resources), and that larval entrainment at a given floodplain may be a function of local geomorphic features (e.g., sand bars, position of floodplain in river bend, number and position of levee openings) and river hydraulics (e.g., local currents, diel river surges). Studies may be necessary to better understand drift and entrainment characteristics of larvae in order to better design floodplain sites.

3.7.3 Sufficient Food Production

Most floodplains produce an abundance of food for fish in the first few months of inundation, although the amount of food produced may vary with floodplain site (Crowl et al. 2002; Gourley and Crowl 2002). Timing of inundation and chronology of food production is critical to growth and survival of entrained larvae. Production in floodplains occurs as a chronology of communities that begins with inundation of dry floodplains and the appearance of rich detrital loads, diatoms, and algae. This is followed by emergence of various zooplanktors, such as rotifers and copepods, that transition into larger forms including cladocerans and various insect larvae (Mabey and Shiozawa 1993; Modde 1997; Crowl et al. 2002; Gourley and Crowl 2002). Rich detritus and invertebrates are important food sources for young fish (Papoulias and Minckley 1990, 1992), and the timing of their appearance with the entrainment of larvae in these floodplains is critical to larval survival (Wydoski and Wick 1998). Larval razorback sucker pass through a “critical period” when nutrition shifts from endogenous (yolk) to exogenous (zooplankton) sources at between 8 and 19 days of age, and they require immediate sources of moderate to high food densities to avoid starvation (Papoulias and Minckley 1990, 1992; see section 3.5).

3.7.4 Suitable Quantity and Quality Of Water

Depression floodplains must have sufficient depth to maintain suitable water quantity and quality for fish to survive during hot summer days and cold winters for at least 1 year. Some depression floodplains may be perched (i.e., elevation higher than the river bed) and maintaining water in these will require excavation to offset evaporative losses, high water temperatures, low oxygen, and complete ice formation in winter. Other depression floodplains may receive surface inflow or seepage that will help to freshen water quality, moderate temperatures, and prevent total freezing. Suitable water quality in these floodplains is critical to insure maximum fish growth and survival.

3.7.5 Reconnection Of Floodplain To Main Channel

Reconnection of a floodplain to the main river channel is critical to completion of the "reset theory" cycle of inundation and desiccation. Reconnection allows the 1 or 2–year old razorback sucker to escape to the river where they can mature and reproduce. Observations of hatchery razorback sucker indicate that age-1 fish will not leave a floodplain during reconnection (Personal Communication, Tim Modde, U.S. Fish and Wildlife Service; Kevin Christopherson, Utah Division of Wildlife Resources). Similar observations have been made for fish 1 to 2 years of age, although these conclusions are preliminary. These observations indicate that young razorback sucker will remain in sheltered floodplains through their first 1–2 years of life, which is consistent with the floodplain management strategy fundamental to this Plan.

Recent studies of hatchery razorback sucker released in floodplains also show that survival in floodplains in the first month is low (<5%), but little or no survival is presumed in the main river channel (Christopherson and Birchell 2002; Birchell and Christopherson 2002). Survival in floodplains after the first month is greatly increased, but it is believed that razorback sucker must be over about 90 mm TL (about 6 months old at low growth rate) and preferably over 230 mm TL (about 17 months old at low growth rate) to survive in the main channel. Fish entrained in a floodplain depression that do not escape to the main channel during a flow connection will become stranded until the following runoff cycle. Given that floodplain connections during spring runoff are typically less than 1 week, the best survival strategy for razorback sucker is believed to be a 24-month residence in a productive floodplain that allows the fish to reach sufficient size for mainstem survival and to escape predators. Until self-sustaining populations become established and multiple spawning sites and floodplains are used by wild fish, it may be necessary to manually transfer fish from floodplains to the main channel when river flows are insufficient to connect floodplains and fish are old enough for mainstem survival.

Levee breaches at key floodplains will increase the frequency of connection with the mainstem and inundation in all but dry and moderately dry years. The hydrologic cycle of the Green River Subbasin typically consists of periods of 3–5 years of wet and moderately wet years followed by periods of dry and moderately dry years (Muth et al. 2000). The "reset theory" is based on this hydrologic cycle in which connection of most floodplains occurs annually in wet years and desiccation (i.e., reset) occurs in intervening dry years. This cycle will also occur in average years with fewer floodplain sites expected to be connected annually. This strategy also recognizes that magnitude, duration, and possibly frequency of inundation will vary among floodplain sites with river stage, and emphasizes the importance of all sites for overall recovery of the endangered fish species.

3.7.6 Desiccation To Reset Floodplain

The key to the "reset theory" is periodic desiccation of the floodplain to reset or kill all remaining fish and reset productivity. Ideally, floodplains should desiccate every fourth year to allow razorback sucker sufficient time to grow and escape to the main river, to limit the numbers of nonnative fish produced in the floodplain, and to insure 100% kill of nonnative fish remaining in the floodplain. Razorback sucker or other native fish may die as well from the desiccation event, but studies and observations show that most native fish species evacuate drying floodplains. This aspect of escapement from floodplains will be part of the evaluation described in this Plan.

Six factors for successful floodplains

1. Connection with the river channel in year 1;
2. Entrainment of drifting larvae in year 1;
3. Sufficient food production timed to arrival of larvae;
4. Suitable quantity and quality of water for 12–24 mo;
5. Reconnection in year 2 or 3 for escape of fish; and
6. Periodic desiccation to reset and kill nonnative fish.

4.0 PRIORITIZATION OF REACHES AND SITES

4.1 Priority River Reaches

Priority river reaches and floodplain sites were identified for this Plan to focus management actions on those areas most likely to benefit razorback sucker and to assist species recovery. Prioritization of river reaches by life stages of razorback sucker was determined for the Green River Subbasin for geomorphology research (LaGory et al. 2003) and was used as the basis for prioritization in this Plan. Of 10 reaches identified for research, three were designated as important to razorback sucker. Reach-habitat scores for all life stages of razorback sucker were highest for Split Mountain to Desolation Canyon (RM 319–216), and high scores were assigned to larvae and juveniles for Labyrinth and Stillwater Canyons (RM 76–0) and Gray Canyon to Labyrinth Canyon (RM 132–76) (Figure 4-1). Of eight habitat types identified for actual and potential use by larval razorback sucker, flooded bottomlands (i.e., floodplains) in restricted meander reaches received the highest scores.

Members of the Green River Team also identified Split Mountain to Desolation Canyon as the most important reach for razorback sucker in the Green River Subbasin, and confirmed the relative importance of Labyrinth and Stillwater Canyons and Gray Canyon to Labyrinth Canyon, based on recent captures of larval and juvenile razorback sucker (Gutermuth et al. 1994; Muth and Wick 1997). Subsequent inventory of the last two reaches revealed few floodplain depressions and primarily tributary and canyon inflows that function as main channel backwaters or terrace floodplains (Nelson and Soker 2002). The only other reach of the Green River Subbasin identified with large numbers of floodplains was Browns Park (RM 396–362), but razorback sucker are not currently in this reach, and are not likely to inhabit the reach because of cool water releases from Flaming Gorge Reservoir (Bestgen 1990). Prioritization of reaches for the Green River was determined for razorback sucker as:

1. Split Mountain to Desolation Canyon (RM 319–216);
2. Labyrinth and Stillwater Canyons (RM 76–0); and
3. Gray Canyon to Labyrinth Canyon (RM 132–76).

Other reaches of the Green River identified by LaGory et al. (2003), including Flaming Gorge Dam to Browns Park, Browns Park, Lodore Canyon, Yampa River to Island Park, Island and Rainbow Parks, Split Mountain Canyon, Desolation and Gray Canyons, are not included in this Plan either because razorback sucker are not in the reach, or because there is little or no floodplain habitat available. Green River tributaries, including the Yampa River, Little Snake River, Duchesne River, White River, Price River, and San Rafael River, are also not included in this Plan for the same reasons. These or other tributaries may become important as self-sustaining populations of razorback sucker become established and the fish disperse. Razorback sucker captured at tributary confluences, such as the San Rafael River (Chart et al. 1999), are considered to have originated in the mainstem Green River and use these inflows transiently.

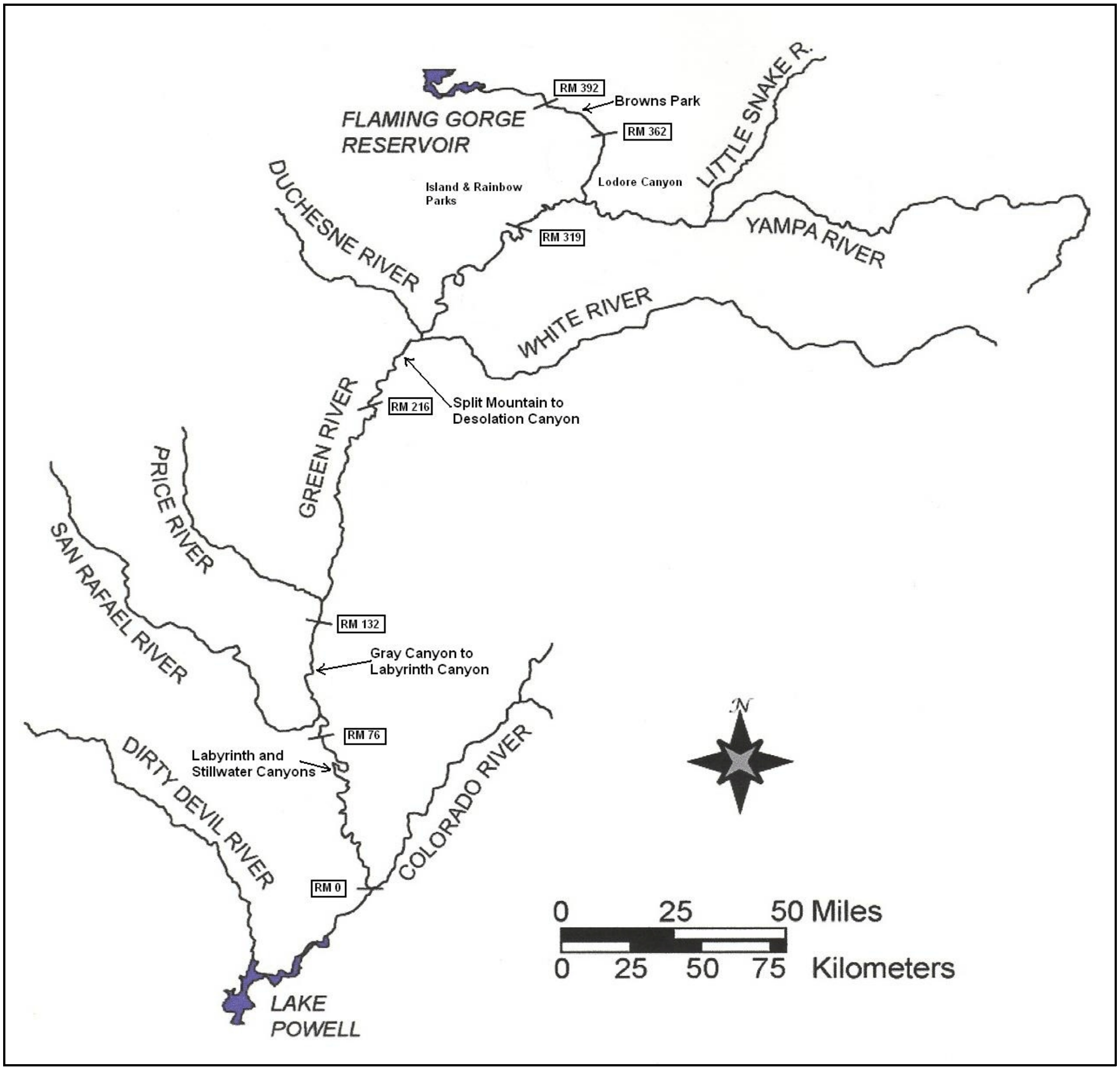


Figure 4-1. The Green River Subbasin and location of the three priority reaches of floodplain habitats. River Miles (RM) are given as distance from confluence of Green and Colorado rivers.

An inventory of existing and potential floodplains during 1993–94 identified 132 sites with a potential of 18,430 acres on 393 miles of the mainstem Green River from Flaming Gorge Dam to the confluence of the Upper Colorado River (Irving and Burdick 1995). Of this total, 7,720 acres were inundated during the May high flow period (18,200 cfs) and 2,438 acres were inundated in the September low flow period (1,560 cfs). The majority of these sites were either shallow depressions (i.e., sites that hold water for a few weeks but fail to hold water year-around) or terraces (i.e., sites that flood and drain with river stage), and inundation may be from groundwater intrusion and not necessarily through surface connection with the river. Based on this inventory, the area of floodplains (and number of sites) in the Split Mountain to Desolation Canyon reach was 11,409 acres (37) at full inundation potential; 6,164 acres (35) at 18,200 cfs; and 1,660 acres (20) at 1,560 cfs (Table 4-1). Area of floodplain inundation in the Labyrinth and Stillwater canyons reach was 2,905 acres (44) at full inundation potential; 121 acres (22) at 18,200 cfs; and 5 acres (1) at 1,560 cfs. Area of floodplain inundation in the Gray Canyon to Labyrinth Canyon reach was 1,333 acres (21) at full inundation potential; 18 acres (5) at 18,200 cfs; and 0 acres at 1,560 cfs.

Numbers of razorback sucker larvae potentially entrained in floodplains within each of the three priority reaches were estimated with the Floodplain Model (Valdez 2004) and used as indices of reach importance (Table 4-2, Figure 4-2). All model parameters were set equal and actual floodplain site locations were used for each reach (Irving and Burdick 1995). It was assumed that a spawning site was located 5 miles upstream from the upstream-most floodplain site of each reach, as is the case with the Split Mountain to Desolation Canyon reach. The location of each floodplain site relative to a spawning bar has a great influence on entrainment and accounts for reach differences in numbers of larvae entrained. These model simulations indicate that larval entrainment at full potential inundation was greatest in the Split Mountain to Desolation Canyon reach (1,322,380), followed by Gray Canyon to Labyrinth Canyon (685,276), and Labyrinth and Stillwater Canyons (379,460). Based on floodplain inundation at 18,200 cfs, estimated larval entrainment was far greatest in the Split Mountain to Desolation Canyon reach (1,322,371), and was similar to entrainment at full potential inundation because nearly all floodplains are inundated (although not necessarily connected) at 18,200 cfs. Entrainment estimates are not provided at 1,560 cfs because there is no surface connection between floodplains and the river at that stage. Reliable inundated floodplains and the presence of a known spawning bar in Split Mountain to Desolation Canyon highlight the importance of this reach in species recovery. The majority of floodplain area identified for each of the three river reaches is either shallow depressions or terraces that do not hold fish for long time periods for maximum growth and survival. Hence, estimates of larval entrainment do not necessarily reflect potential fish survival and recruitment from these floodplains.

Table 4-1. Areas of floodplain inundation in the three priority reaches of the Green River Subbasin at full inundation potential and flows of 18,200 cfs and 1,560 cfs (data from Irving and Burdick [1995]). River Mile location is distance along the river center line from the confluence with the Colorado River. The majority of these sites were either shallow depressions (i.e., sites that fail to hold water year-around) or terraces (i.e., sites that flood and drain with river stage), and inundation may be from ground-water intrusion and not necessarily through surface connection with the river.

Reach	Location (River Mile)	Inundation Potential		05/25/93 (18,200 cfs)		09/28/93 (1,560 cfs)	
		No. Sites	Acres	No. Sites	Acres	No. Sites	Acres
1. Split Mountain to Desolation Canyon	216–319	37	11,408.5	35	6,164.2	20	1,659.8
2. Labyrinth and Stillwater Canyons	0–76	44	2,904.9	22	120.9	1	4.8
3. Gray Canyon to Labyrinth Canyon	76–132	21	1,332.7	5	17.7	0	0

Table 4-2. Total numbers of razorback sucker larvae potentially entrained in floodplains of each of the three priority reaches of the Green River at full inundation potential and flows of 18,200 cfs. Estimated entrainment is based on the Floodplain Model with the following assumptions: a spawning bar is located 5 miles upstream from the upstream-most floodplain site; number of adults = 5,800; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; mile-to-mile survival of drifting larvae = 90%; entrainment at each floodplain site = 10%; number of larvae escaping the spawning bar = 5,469,955.

Reach	Inundation Potential		05/25/93 (18,200 cfs)	
	Acres	No. Entrained	Acres	No. Entrained
1. Split Mountain to Desolation Canyon	11,408.5	1,322,380	6,164.2	1,322,371
2. Labyrinth and Stillwater Canyons	2,904.9	379,460	120.9	192,426
3. Gray Canyon to Labyrinth Canyon	1,332.7	685,276	17.7	26,471

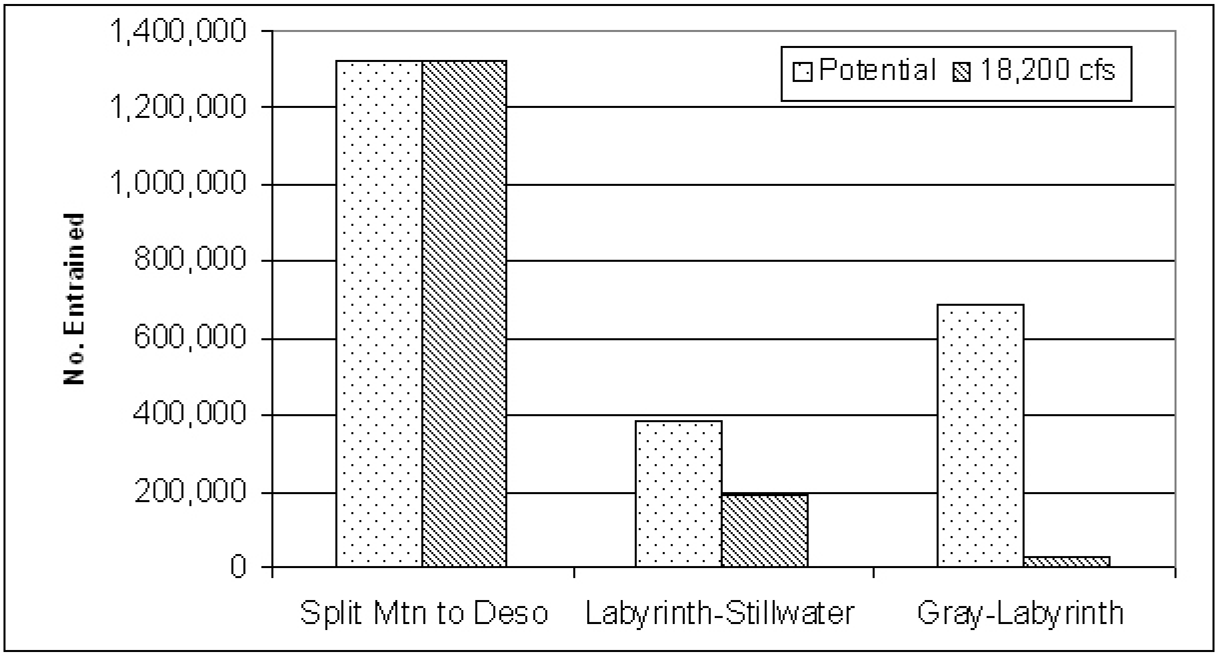


Figure 4-2. Total numbers of razorback sucker larvae potentially entrained in floodplains of each of the three priority reaches of the Green River at full inundation potential and flows of 18,200 cfs. Estimated entrainment is based on the Floodplain Model with the following assumptions: a spawning bar is located 5 miles upstream from the upstream-most floodplain site; number of adults = 5,800; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; mile-to-mile survival of drifting larvae = 90%; entrainment at each floodplain site = 10%; number of larvae escaping the spawning bar = 5,469,955.

4.2 Priority Floodplain Sites

A floodplain inventory (Irving and Burdick 1995) prioritized river subreaches and floodplain sites on the basis of status of land ownership, proximity to spawning bar, June connection to river, and potential network of sites. The majority of sites were small with short-term inundation. Top ranked subreaches were (a) Ouray National Wildlife Refuge (ONWR), (b) Jensen to Brennan Bottom, and (c) sites downstream of Ouray; 32 floodplains in these subreaches ranked as the top 11 sites (Table A-1). These sites are within the Split Mountain to Desolation Canyon reach, which corresponds to the reach with the highest score for geomorphology research (LaGory et al. 2003) and the most important reach selected by the Green River Team. The inventory also identified 44 sites in the Labyrinth and Stillwater Canyons reach that all ranked 17th (Table A-2), and 21 sites in the Gray Canyon to Labyrinth Canyon reach that ranked either 16, 17, or 18th (Table A-3). The following sections describe the three priority reaches and the numbers of floodplain sites within each reach.

4.2.1 Split Mountain to Desolation Canyon

This reach is 103 miles long and has 37 potential floodplain sites for a total of 11,408.5 acres; 35 sites (6,164.2 acres) were inundated at 18,200 cfs on May 25, 1993; and 20 sites (1,659.8 acres) were inundated at 1,560 cfs on September 28, 1993 (Table 4-1; Irving and Burdick 1995); inundation may be from ground-water intrusion and not necessarily through surface connection with the river. The Recovery Program has access to or has acquired 16 floodplain sites in this reach with the greatest probability of success as nursery and rearing habitats of razorback sucker (Nelson and Soker 2002; Table 4-3; Figure 4-3). Estimated area of inundation for these 16 floodplain sites at the Green River flow recommendation of 18,600 cfs is 4,448 acres, but area with surface connection to the river is 3,853 acres. Two sites have partial or no surface connection to the river because of existing earthen dikes. Selection of these 16 sites was confirmed by the Green River Team. Of these 16 sites, four have easements that were acquired by the Recovery Program from six property owners (i.e., 1, 2, 6, 16). Five sites are on lands administered by the Bureau of Land Management (i.e., 5, 7–10), and five sites are administered by the ONWR (i.e., 11–15). Site 15 is owned by the Ute Indian Tribe and managed by the ONWR. Objectives and management actions for the Split Mountain to Desolation Canyon reach are presented in section 5.1, and objectives and management actions for each floodplain site are presented in section 6.0. There are several hundred acres of terrace or small depression floodplains that form in this reach at 18,600 cfs to which the Recovery Program does not have access but may serve as nursery habitat for razorback sucker. These areas are either under private ownership unwilling to allow easement access or are small depressions and pockets that collectively constitute a large area. These floodplains are considered a buffer to estimated fish production and recruitment.

4.2.2 Labyrinth and Stillwater Canyons

This reach is 76 miles long and has 44 potential floodplain sites for a total of 2,904.9 acres; 22 sites (120.9 acres) were inundated at 18,200 cfs on May 25, 1993; and 1 site (4.8 acres) was inundated at 1,560 cfs on September 28, 1993 (Table 4-1, A-2; Irving and Burdick 1995); inundation may be from ground-water intrusion and not necessarily through surface connection with the river. Site observations, cross sections, and color infrared aerial photography revealed few depression floodplains in the Labyrinth and Stillwater Canyons reach, and most sites are perched with little potential for prolonged inundation (Flo Engineering 1996). Objectives and management actions for this reach are presented in section 5.2, but no site-specific objectives or management actions are provided because of low potential for these floodplain sites.

4.2.3 Gray Canyon to Labyrinth Canyon

This reach is 56 miles long and has 21 potential floodplain sites for a total of 1,332.7 acres; 5 sites (17.7 acres) were inundated at 18,200 cfs on May 25, 1993; and 0 sites were inundated at 1,560 cfs on September 28, 1993 (Table 4-1, A-3; Irving and Burdick 1995); inundation may be from ground-water intrusion and not necessarily through surface connection with the river. Site observations, cross sections, and color infrared aerial photography revealed few depression floodplains in the Gray Canyon to Labyrinth Canyon reach, and most sites are perched with little potential for prolonged inundation (Flo Engineering 1996). Objectives and management actions for this reach are presented in section 5.3, but no site-specific objectives or management actions are provided because of low potential for these floodplain sites.

Table 4-3. Location, acres inundated, and ownership of 16 priority floodplain sites in the Split Mountain to Desolation Canyon reach. 18,600 cfs reflects Green River flow recommendation; areas in parentheses do not presently have surface connection to the river. Total potential inundation is 4,448 acres.

Site	Location (River Miles)	Estimated Acres Inundated at 18,600 cfs	Ownership
1. Thunder Ranch	305.5	(330)	Perpetual easement from landowner by Recovery Program
2. IMC	302.5	4	Perpetual easement from landowner by Recovery Program
3. Stewart Lake	300	570	Utah Division of Wildlife Resources
4. Sportman's Lake	297	132	Uintah Sportsman's Club
5. Bonanza Bridge	289.5	28	Bureau of Land Management
6. Richens, Slaugh	288	45	Perpetual easement from 3 landowners by Recovery Program
7. Horseshoe Bend	285	22	Bureau of Land Management
8.The Stirrup	276	28	Bureau of Land Management
9. Baeser Bend	273	47	Bureau of Land Management
10. Above Brennan	269	50	Bureau of Land Management
11.Johnson Bottom	264.5	146	Ouray National Wildlife Refuge
12. Leota Ponds	258.5	1,016	Ouray National Wildlife Refuge
13. Wyasket Lake	256	850	Ouray National Wildlife Refuge
14. Sheppard Bottom	253	35 (300)	Ouray National Wildlife Refuge
15a. Old Charlie–Main	251	336	Ute Tribe, managed by Ouray National Wildlife Refuge
15b. Old Charlie–Diked	251	81	Ute Tribe, managed by Ouray National Wildlife Refuge
16. Lamb Property	244	463	Perpetual easement from landowner by Recovery Program

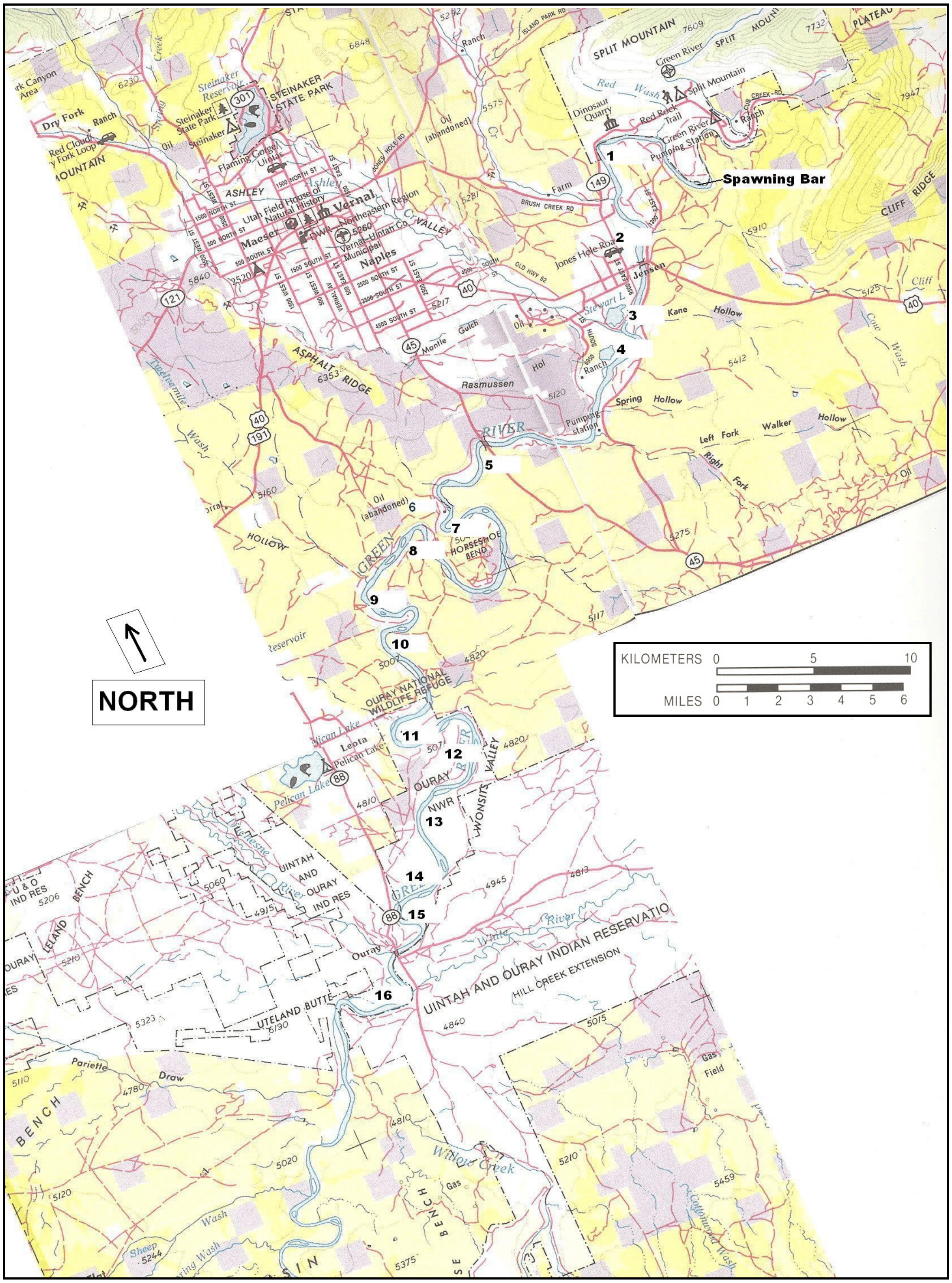


Figure 4-3. Sixteen priority floodplain sites in the Split Mountain to Desolation Canyon reach. See Table 4-3 for site numbers, names, and acres of inundation.

5.0 REACH OBJECTIVES AND MANAGEMENT ACTIONS

This section describes roles in recovery, objectives, and management actions for the three priority reaches identified for the Green River Subbasin in section 4.0. Objectives and management actions for each reach are summarized in Table 5-1 at the end of this section.

5.1 Split Mountain To Desolation Canyon

5.1.1 Role In Recovery

The Split Mountain to Desolation Canyon reach is the focal area for establishing a self-sustaining population of 5,800 adults to meet species recovery goals for the Green River Subbasin (U.S. Fish and Wildlife Service 2002a). This reach contains the largest number of wild razorback sucker in the upper basin, an active spawning bar, and sufficient numbers and acreage of floodplain habitat for restoration and management by the Recovery Program. Establishment and expansion of a self-sustaining population of razorback sucker in this reach is likely to result in dispersal of fish to other reaches with concomitant use of other nursery floodplain sites and possibly other spawning sites. Management actions in other reaches of the Green River Subbasin should be identified as those actions necessary to maintain self-sustaining populations of razorback sucker and bonytail, based on evidence of population expansion from sampling during other ongoing Recovery Program activities; e.g., population estimates for Colorado pikeminnow and humpback chub, as well as nonnative fish control programs.

5.1.2 Objectives and Management Actions

Objective R1-1. Prioritize and coordinate recovery activities for razorback sucker and bonytail in this reach.

Recovery Program activities for razorback sucker in the Green River Subbasin should be prioritized for the Split Mountain to Desolation Canyon reach. This reach is important because: (1) the only known spawning site used regularly by wild and hatchery razorback sucker is located at the upstream end of this reach, (2) floodplain sites that flood at moderate to high flows are strategically located in this reach, (3) numerous floodplain sites are accessible for Recovery Program restoration and management, (4) historic data indicate that this reach was the population center for razorback sucker in the Green River Subbasin, (5) Green River flow recommendations ensure inundation of floodplains in this reach on a regular basis, and (6) ecological conditions, water quality, and water temperature are suitable for the species. This reach also provides the best opportunity to initiate recovery of bonytail because it is immediately downstream from the last known capture location of large numbers of wild bonytail in the subbasin (Vanicek 1967), and management of habitat for razorback sucker is likely to also benefit the bonytail.

✔ **Management Action R1-1A. Prioritize Recovery Program activities for razorback sucker and bonytail in the Green River Subbasin**.

The Recovery Program is conducting numerous simultaneous activities in the Split Mountain to Desolation Canyon reach. These activities should be coordinated in a manner that is consistent with program elements and prioritizes floodplain management of the Green River Subbasin in the Split Mountain to Desolation Canyon reach. Floodplain restoration, hatchery augmentation, nonnative fish control, and research activities should be directed appropriately to this reach to ensure establishment and maintenance of self-sustaining populations of razorback sucker as well as bonytail. Activities being conducted by the Recovery Program can support and supplement floodplain management activities and result in time, labor, and cost savings, as well as less handling stress to the fish. For example, information on numbers of fish, sizes, capture locations, habitat use, etc. gathered on razorback sucker and bonytail during mark-recapture population estimates for Colorado pikeminnow or humpback chub should be assimilated and evaluated annually as part of a monitoring program to assess stocking success and establishment of self-sustaining populations. This prioritization is also consistent with priorities for geomorphology research in the Green River Subbasin (LaGory et al. 2003).

✔ **Management Action R1-1B. Coordinate with the Utah Division of Wildlife Resources, Bureau of Reclamation, and U.S. Fish and Wildlife Service on management of Stewart Lake to ensure that agency management objectives for this site are not negatively impacted.**

The UDWR manages Stewart Lake as a waterfowl management area with assistance from Reclamation and the Service for remediation of selenium. Stewart Lake is only 11 miles downstream from the razorback sucker spawning bar, and could be an important floodplain site for recovery because of this high potential for larval entrainment. Wild razorback sucker larvae and adults have been captured at this site, confirming this potential. The Recovery Program should coordinate with UDWR, Reclamation, and the Service to identify management opportunities for Stewart Lake to benefit razorback sucker without negatively impacting agency management objectives for this site.

✔ **Management Action R1-1C. Coordinate with the Ouray National Wildlife Refuge (ONWR) on floodplain management to ensure that ONWR goals and objectives are not negatively impacted.**

The majority of floodplain depression acreage in the Split Mountain to Desolation Canyon reach is located in the ONWR. Goals and objectives of the ONWR Comprehensive Conservation Plan (U.S. Fish and Wildlife Service 2000) include: *"Provide habitats that support the recovery of Colorado River endangered fishes (razorback sucker, Colorado pikeminnow, humpback chub),"* and identify the strategy to *"Coordinate with the Recovery Program on proposed habitat management actions..."* Five of the 16 priority floodplain sites identified in this Plan are owned or managed by ONWR for a total of 2,729 potential acres, or about 61% of total floodplain area in the reach (Table 4-3). Some of these floodplain sites have been diked and are being managed for waterfowl production by ONWR. The Recovery Program should coordinate with ONWR to identify floodplain sites that can be managed to mutually benefit management goals and objectives of both programs. Possible restoration activities include: levee breaches, dike removal, water control structures, deepening shallow floodplain depressions, and periodic inundation and desiccation of floodplains. Site-specific management actions for ONWR floodplains are described in section 6.2 of this Plan.

Objective R1-2. Identify, acquire, protect, restore, and manage floodplain sites to benefit razorback sucker and bonytail.

The Recovery Program has inventoried and identified all floodplain sites in the Split Mountain to Desolation Canyon reach, and acquired most available easements for program protection and management. Restoration activities have been initiated on some floodplain sites and these are being managed to benefit razorback sucker along with studies to evaluate restoration, as well as growth and survival of fish. Other sites are in need of restoration, as described in this Plan, and some less desirable sites are reserved as contingencies in case additional restoration becomes necessary.

✔ **Management Action R1-2A. <u>Identify, acquire, protect, and manage floodplain sites</u>.**

Acquisition, protection, and management of floodplain sites in the Split Mountain to Desolation Canyon reach are vital to recovery of razorback sucker and possibly bonytail. The Recovery Program has identified all floodplain habitats in this reach and acquired six private easements on four floodplain sites (Nelson and Soker 2002). Additionally, 11 sites under administration of State and Federal agencies, have been identified with greatest potential for restoration and management (see Table 4-3). The Recovery Program will manage these sites in cooperation with the administering agency. Model simulations indicate that these 16 floodplain sites contain sufficient area to recover the razorback sucker, but restoration is necessary to reconfigure some sites to function as long-term floodplain depressions. Floodplain acquisition in this reach is no longer necessary and management of some sites and restoration and management of other sites is necessary to assist species recovery (see site-specific management actions in section 6.2).

✔ **Management Action R1-2B. <u>Restore and evaluate key floodplain sites most likely to benefit razorback sucker</u>.**

Sixteen priority floodplain sites have been identified for possible restoration and management. Levees have been breached at eight sites administered by Federal agencies (i.e., Bonanza Bridge, Horseshoe Bend, The Stirrup, Baeser Bend, Above Brennan, Johnson Bottom, Leota Ponds, and Old Charlie Wash) resulting in 274 acres of inundated floodplains at 13,000 cfs. The efficacy of levee breaches for inundation and larval entrainment has not been fully evaluated because of low water years following restoration. Further restoration may be necessary at some sites to ensure adequate inundation, larval entrainment, and retention of water quantity and quality for fish. Additional restoration should be prioritized starting with the upstream-most sites closest to the known razorback sucker spawning bar to maximize larval entrainment. The most important of these floodplains is located on Thunder Ranch, a private holding about 5 miles downstream of the spawning bar. The second priority floodplain for restoration is Stewart Lake, followed by Leota Ponds and Johnson Bottom (see section 6.2 for site descriptions).

✔ **Management Action R1-2C. Manage river flows to inundate key floodplain sites on a timely basis.**

Flow and temperature recommendations for the Green River downstream of Flaming Gorge Dam (Muth et al. 2000) in spring call for *"S[s]ignificant inundation of floodplain habitat and off-channel habitats ... to establish river-floodplain connections and provide warm, food-rich environments for growth and conditioning of razorback suckers (especially young)..."* in wet years (0–10% exceedence) and moderately wet years (10–30% exceedence), and in at least 1 of 4 average years (30–70% exceedence). There would be little floodplain inundation in moderately dry years (70–90% exceedence) and dry years (90–100% exceedence). Flow recommendations will be implemented as part of the Environmental Impact Statement on Operations of Flaming Gorge Dam, and should be evaluated to ensure that specified floodplain inundation is achieved.

Objective R1-3. Provide adequate floodplain habitat necessary for establishment and maintenance of a self-sustaining population of razorback sucker.

Recovery Program activities should prioritize and implement those activities that will most effectively provide adequate floodplain habitat for establishment of a self-sustaining population of razorback sucker. Establishment of a self-sustaining population of razorback sucker in the Green River Subbasin is estimated to require 14 years, or by about 2015 (U.S. Fish and Wildlife Service 2002a). The most likely center for this population is the Split Mountain to Desolation Canyon reach because of an existing spawning bar and a large number and acreage of available floodplain sites, which can likely support a population of at least 5,800 adult razorback sucker, the species recovery goals target.

✔ **Management Action R1-3A. Identify habitat requirements of razorback sucker through use of hatchery fish.**

Habitat of hatchery and wild razorback sucker should be documented and information assimilated as part of the Recovery Program's database. The Recovery Program should ensure that ongoing activities record sufficient data to document capture location and habitat of any razorback sucker captured in the wild. This action can be achieved by including a requirement with scientific collecting permits for appropriate data collection and timely delivery of data to the Database Manager. Assimilation of information on habitat use will help to determine those management actions necessary to provide suitable habitat for razorback sucker.

✔ **Management Action R1-3B. Identify strategies to maximize growth, survival, and recruitment of hatchery and wild razorback sucker.**

Use of hatchery fish should continue to augment the wild population, and excess production should be used for studies of growth and survival in floodplains to identify best stocking strategies and floodplains most likely to benefit razorback sucker. Research is being conducted to assess floodplain conditions that result in the best growth, survival, and recruitment (Christopherson and Birchell 2002; Birchell and Christopherson 2002). This information should be assimilated to determine: (a) monthly growth and survival of different age hatchery fish placed in different floodplain sites, (b) monthly survival and growth of different age hatchery fish at various densities of nonnative fishes, (c) ability of floodplain sites to hold fish for up to 24 months, and (d) size at which fish leave floodplains for the river. Additional studies of growth and survival should be conducted pending outcome of this assimilation of information and identification of further necessary studies.

✔ **Management Action R1-3C. Identify strategies to maximize entrainment of drifting larvae.**

Maximum entrainment of drifting razorback sucker larvae in floodplain sites is vital to species conservation. The existing razorback sucker spawning bar at RM 311 has the potential to produce about 5.5 million drifting larvae with a population of 5,800 adults. Those floodplain sites closest to the spawning bar have the greatest potential to entrain drifting larvae (see Appendix B: Floodplain Model Simulations #2, #3, and #4). Assuming a survival rate of 2% from egg to larvae emergence, no fish would be produced by floodplains below 27 miles from the spawning bar at 80% mile-to-mile entrainment; none below 60 miles at 90% mile-to-mile entrainment; and only 36 fish would be produced 70 miles below the spawning bar. Key floodplain sites should be structured to maximize entrainment, including optimal location of inflows. Studies of inflow location show that upstream breaches appear to entrain a greater volume of water (Nelson and Soker 2002) and it is assumed that this equates to greater larval entrainment. Recent preliminary studies with artificial beads show that entrainment may not be proportional to the amount of water flowing into a floodplain site (Personal Communication, Kevin Christopherson, Utah Division of Wildlife Resources). This relationship may need to be investigated for a better understanding.

✔ **Management Action R1-3D. Investigate establishment of additional spawning bars.**

Additional spawning bars may become naturally established if the population of razorback sucker is increased and expanded through recovery efforts. Geomorphology assessments may be appropriate to protect and maintain spawning bars. Possibly, the current known spawning bar at RM 311 continues to be used by wild fish because suitable floodplain sites downstream have enabled larvae and young of that spawning stock to survive and not necessarily because the site is geomorphologically or hydraulically unique.

Additional spawning bars could enhance and accelerate recovery of razorback sucker, as demonstrated by the Floodplain Model (see Appendix B: Floodplain Model Simulation #4) using the same set of parameters for two runs; one with a single spawning bar at the upstream end and a second with an additional spawning bar midway through the reach. The second bar is located at a large cobble/gravel bar where numerous razorback sucker have been captured and radio-tracked (Valdez and Masslich 1989; Tyus and Karp 1990). The number of adults (5,800) was equally divided into 2,900 for each of the two spawning sites, which resulted in larval production also divided into two spawning sites; i.e., 2,734,978 larvae emerging at each site. A second spawning site increased potential larval entrainment by 15% (196,597 to 225,968), 11% (595,875 to 672,264), and 7% (1,263,768 to 1,362,857) for 80%, 90%, and 95% mile-to-mile survival. A second spawning bar also increased potential recruitment from 30%, 36%, and 36% to 33%, 40%, and 40% for low, moderate, and high growth rates, respectively.

✔ **Management Action R1-3E. <u>Evaluate adequacy of floodplain habitat</u>.**

The adequacy of floodplain habitat restoration and management should be part of the ongoing evaluation of this Plan. Key responses necessary for recovery of razorback sucker (U.S. Fish and Wildlife Service 2001a) and bonytail (U.S. Fish and Wildlife Service 2001b) are (a) population size of 5,800 adult razorback sucker and 4,400 adult bonytail, and (b) mean estimated recruitment of age–3 naturally produced fish equal to or exceeding mean annual adult mortality. The recovery goals specify that recruitable sized fish must be naturally produced and not composed of hatchery fish released into the wild.

Objective R1-4. Identify habitats necessary for establishment and maintenance of a self-sustaining population of bonytail.

Little is known of habitat used by wild bonytail. Recovery factor criteria for bonytail (U.S. Fish and Wildlife Service 2002b) require that:

> *"Habitats identified that are necessary for the establishment and maintenance of bonytail populations in the Green River and upper Colorado River subbasins...".*

Identification of habitats will require continued release of hatchery bonytail into the wild for observation of habitats used by these fish. A formal monitoring program is not recommended until survival and numbers of stocked fish are sufficient and monitoring is deemed necessary by the Recovery Program.

✔ **Management Action R1-4A. <u>Assimilate information on habitat of hatchery bonytail in the wild</u>.**

Habitat of hatchery and wild bonytail should be documented and assimilated as part of the Recovery Program's database. The Recovery Program should ensure that ongoing activities record sufficient data to document capture location and habitat of any bonytail captured in the wild. This action can be achieved by including a requirement with scientific collecting permits for appropriate data collection and timely delivery of data to the Database Manager. Assimilation of information on habitat use will help to determine those management actions necessary to provide suitable habitat for bonytail.

✔ **Management Action R1-4B. Identify strategies to maximize growth, survival, and recruitment of hatchery and wild bonytail.**

Use of hatchery fish should continue to augment the wild population, and excess production should be used for studies of growth and survival in floodplains to identify best stocking strategies and floodplains most likely to benefit the bonytail. Research is being conducted to assess floodplain conditions that result in the best growth, survival, and recruitment for both razorback sucker and bonytail (Christopherson and Birchell 2002; Birchell and Christopherson 2002). This information should be assimilated to determine: (a) monthly growth and survival of different age hatchery fish placed in different floodplain sites, (b) monthly survival and growth of different age hatchery fish at various densities of nonnative fishes, (c) ability of floodplain sites to hold fish for up to 24 months, and (d) size at which fish leave floodplains for the river. Additional studies of growth and survival should be conducted pending outcome of this assimilation of information and identification of further necessary studies.

Objective R1-5. Determine level of nonnative fish control in floodplains necessary to recover razorback sucker and bonytail.

Nonnative fishes prey on and compete with native fish species and limit recovery of endangered species (Lentsch et al. 1996b; Tyus and Saunders 1996). Nonnative fish control methods have been investigated in floodplain habitats (Lentsch et al. 1996b), but definitive control methods have not been identified. Control of nonnative fishes in the mainstem and tributaries of the Green River Subbasin continue through the Recovery Program, and possible strategies have been identified for nonnative fish control in floodplain sites. These strategies include the "reset theory" of floodplain management, or periodic inundation and desiccation to rid these habitats of nonnative species (Nelson and Soker 2002). These and other strategies need to be further evaluated to determine the level of nonnative fish control necessary to recover razorback sucker and bonytail.

✔ **Management Action R1-5A. Ensure that management actions associated with floodplain activities are consistent with the Recovery Program's element to manage and control nonnative species.**

The Recovery Program has past and ongoing control activities of nonnative fish and evaluations in the Green River Subbasin. These include control of channel catfish, northern pike, and smallmouth bass in the mainstem and tributaries, and control of small-bodied fishes in backwaters and floodplains. Management actions associated with floodplain activities should be consistent with ongoing Recovery Program actions to manage and control nonnative species.

✔ **Management Action R1-5B. Evaluate the "reset theory" to reduce negative impacts of nonnatives fishes in floodplains.**

The "reset theory" of floodplain management will be implemented on a 2 or 3–year cycle of inundation and desiccation of floodplain depressions to minimize negative impacts of nonnative fishes. Floodplain sites identified in this Plan should be evaluated to determine the effectiveness of this strategy.

5.2 Labyrinth and Stillwater Canyons

5.2.1 Role In Recovery

Labyrinth and Stillwater Canyons (RM 0–76) is the second most important reach in the Green River Subbasin for recovery of razorback sucker. This reach has the potential as a supporting role for recovery, based on recent captures of razorback sucker. Collections in 1993–1996 yielded a total of 363 larval razorback sucker from the lower Labyrinth and upper Stillwater Canyon area; 80% were from Millard Canyon, a flooded side canyon at RM 33.5, and 19% were from the Anderson Bottom/Bonita Bend area at RM 31 (Muth et al. 1998). Small size and estimated young age of these larvae indicate they originated from spawning activity within this reach of the lower Green River. Despite the presence of larvae in this reach, there is little evidence of survival and recruitment of razorback sucker in the lower Green River (Modde et al. 1996). Floodplain potential in this reach is limited because most floodplains are perched terraces with little opportunity for prolonged retention of water without substantial mechanical excavation. Floodplain restoration and management are not currently recommended for this reach, although restoration may be necessary if activities in other reaches are not effective, or if this habitat is necessary to maintain a self-sustaining population of razorback sucker in the Green River Subbasin.

5.2.2 Objectives And Management Actions

Objective R2-1. Establish as a second priority reach for recovery of razorback sucker and bonytail.

The Labyrinth and Stillwater Canyons reach is 334 miles downstream from Flaming Gorge Dam and is the furthest downstream reach of the Green River. Flow management for this reach is difficult and more unpredictable than for more upstream reaches because of various water diversions, tributary inflows, and longitudinal characteristics of losing and gaining reaches. The remoteness of this reach, and the fact that the lower 47 miles is within Canyonlands National Park, restricts the amount of restructuring that is possible for floodplain sites. Nevertheless, establishment of a self-sustaining population of razorback sucker in the middle Green River will likely result in dispersal of fish into the lower Green River. The Razorback Sucker Recovery Goals (U.S. Fish and Wildlife Service 2002a) estimate that populations of razorback sucker are likely to become established under a metapopulation framework within the Green River

Subbasin, as well as within the Upper Colorado River Subbasin. Future floodplain restoration in this reach may be necessary to maintain the population.

✔ **Management Action R2-1A. <u>Assimilate evidence of population expansion</u>.**

The Labyrinth and Stillwater Canyons reach should be observed for evidence of population expansion of razorback sucker from upstream recovery efforts. A subbasin-wide monitoring program is not recommended because numbers of razorback sucker in the system are currently low. Other monitoring activities, such as spring electrofishing for population estimates of Colorado pikeminnow, fall trammel-netting for humpback chub population estimates, nonnative fish control, and annual larval drift-netting and light-trapping will likely detect the initial signs of a positive population response (e.g., catches of various sizes of fish and increased larval drift). An appropriate monitoring program can be developed and implemented to evaluate numbers and distribution of fish, as well as appropriate floodplain management actions, as deemed necessary by the Recovery Program.

Objective R2-2. Implement floodplain management actions, as necessary, following population expansion.

The Labyrinth and Stillwater Canyons reach should not receive immediate or direct management attention because: (a) it currently lacks an active spawning site, (b) floodplain potential is limited, and (c) restructuring of floodplain sites is logistically difficult.

✔ **Management Action R2-2A. <u>Implement floodplain management actions, as necessary</u>.**

Management actions should be developed and implemented, as necessary.

5.3 Gray Canyon to Labyrinth Canyon

5.3.1 Role In Recovery

Gray Canyon to Labyrinth Canyon (RM 76–132) is the third most important reach in the Green River Subbasin for recovery of the razorback sucker. This reach also has the potential as a supporting role for recovery, based on recent captures of razorback sucker. Collections in 1993–1996 yielded 76 larvae from the San Rafael River confluence at RM 97 (Muth et al. 1998) that probably originated from spawning within this reach of the lower Green River. Floodplain potential in this reach is limited because most floodplains are perched terraces with little retention of water without substantial mechanical excavation. Floodplain restoration and management are not currently recommended for this reach, although restoration may be necessary if other restoration activities are not effective, or if this habitat is necessary to maintain a self-sustaining population of razorback sucker in the Green River Subbasin.

5.3.2 Objectives And Management Actions

Objective R3-1. Establish as a third priority reach for recovery of razorback sucker and bonytail.

The Gray Canyon to Labyrinth Canyon reach is 278 miles downstream from Flaming Gorge Dam and is the second furthest downstream reach of the Green River. Flow management for this reach is difficult and more unpredictable than for more upstream reaches because of various tributary inputs, water diversions, and losing and gaining reaches. The remoteness of this reach greatly limits the amount of restructuring of floodplain sites.

✔ **Management Action R3-1A. <u>Assimilate evidence of population expansion</u>.**

The Gray Canyon to Labyrinth Canyon reach should be observed for evidence of population expansion of razorback sucker from upstream recovery efforts. A subbasin-wide monitoring program is not recommended because numbers of razorback sucker in the system are low. Other monitoring activities, such as spring electrofishing for population estimates of Colorado pikeminnow, fall trammel-netting for humpback chub population estimates, nonnative fish control, and annual larval drift-netting and light-trapping will likely detect the initial signs of a positive population response (e.g., catches of various sizes of fish and increased larval drift). An appropriate monitoring program can be developed and implemented to evaluate numbers and distribution of fish, as well as appropriate floodplain management actions, as deemed necessary by the Recovery Program.

Objective R3-2. Implement floodplain management actions, as necessary, following population expansion.

The Gray Canyon to Labyrinth Canyon reach should not receive immediate or direct management attention because: (a) it currently lacks an active spawning site, (b) floodplain potential is limited, and (c) restructuring of floodplain sites is logistically difficult.

✔ **Management Action R3-2A. <u>Implement floodplain management actions, as necessary</u>.**

Management actions should be developed and implemented, as necessary.

Table 5-1. Summary of objectives and management actions for the three priority reaches of the Green River Subbasin.

Reach Objectives	Management Actions
Reach 1: Split Mountain To Desolation Canyon	
R1-1. Prioritize and coordinate recovery activities for razorback sucker and bonytail in this reach.	R1-1A. Prioritize Recovery Program activities for razorback sucker and bonytail in the Green River Subbasin.
	R1-1B. Coordinate with the Utah Division of Wildlife Resources, Bureau of Reclamation, and U.S. Fish and Wildlife Service on management of Stewart Lake to ensure that agency management objectives for this site are not negatively impacted.
	R1-1C.Coordinate with the Ouray National Wildlife Refuge (ONWR) on floodplain management to ensure that ONWR goals and objectives are not negatively impacted.
R1-2. Identify, acquire, protect, restore, and manage floodplain sites to benefit razorback sucker and bonytail.	R1-2A. Identify, acquire, protect, and manage floodplain sites.
	R1-2B. Restore and evaluate key floodplain sites most likely to benefit razorback sucker.
	R1-2C. Manage river flows to inundate key floodplain sites on a timely basis.
R1-3. Provide adequate floodplain habitat necessary for establishment and maintenance of a self-sustaining population of razorback sucker.	R1-3A. Identify habitat requirements of razorback sucker through use of hatchery fish.
	R1-3B. Identify strategies to maximize growth, survival, and recruitment of hatchery and wild razorback sucker.
	R1-3C. Identify strategies to maximize entrainment of drifting larvae.
	R1-3D. Investigate establishment of additional spawning bars.
	R1-3E. Evaluate adequacy of floodplain habitat.
R1-4. Identify habitats necessary for establishment and maintenance of a self-sustaining population of bonytail.	R1-4A. Assimilate information on habitat of hatchery bonytail in the wild.
	R1-4B. Identify strategy to maximize growth, survival, and recruitment of hatchery and wild bonytail.
R1-5. Determine level of nonnative fish control in floodplains necessary to recover the razorback sucker and bonytail.	R1-5A. Ensure that management actions associated with floodplain activities are consistent with the Recovery Program's element to manage and control nonnative species.
	R1-5B. Evaluate the "reset theory" to reduce negative impacts of nonnatives fishes in floodplains.

Table 5-1. Continued.

Reach Objectives	Management Actions
Reach 2: Labyrinth and Stillwater Canyons	
R2-1. Establish as a second priority reach for recovery of razorback sucker and bonytail.	R2-1A. Assimilate evidence of population expansion.
R2-2. Implement floodplain management actions, as necessary, following population expansion.	R2-2A. Implement floodplain management actions, as necessary.
Reach 3: Gray Canyon to Labyrinth Canyon	
R3-1. Establish as a third priority reach for recovery of razorback sucker and bonytail.	R3-1A. Assimilate evidence of population expansion.
R3-2. Implement floodplain management actions, as necessary, following population expansion.	R3-2A. Implement floodplain management actions, as necessary.

6.0 MANAGEMENT OF FLOODPLAIN SITES

6.1 Summary Of Past Restoration Actions

The Recovery Program has access to 16 floodplain sites in the Green River Subbasin identified in this Plan for restoration and management. These sites are either under the administration of Federal or State agencies, or the Recovery Program has acquired easements from private property owners (see section 4.2). Table 6-1 summarizes previous actions by the Recovery Program on each site, including easements, levee breaches, and coordination, as well as acres of inundation at river flows of 13,000 cfs and 18,600 cfs. Easements have been acquired from six property owners on four sites in the Green River Subbasin, including Thunder Ranch, IMC, Richens/Slaugh/Slaugh (3 owners), and the Lamb Property. These acquisitions total 1,008.1 acres of property with approximately 824 acres of floodplains at a cost of $891,850. The Recovery Program has also breached levees at eight sites, including Bonanza Bridge, Horseshoe Bend, the Stirrup, Baeser Bend, Above Brennan, Johnson Bottom, Leota Ponds, and Old Charlie Wash. Additionally, ONWR removed or breached internal dikes at Johnson Bottom and Leota Ponds to facilitate water management. These levee breaches and dike removals allow the river to flood a total of 2,263 acres starting at about 13,000 cfs (Table 6-1). Area of inundation at 18,600 cfs under existing conditions is 3,853 acres. Areas of inundation at 13,000 cfs and 18,600 cfs are based on inventories, surveys, and aerial photography (Irving and Burdick 1995; Irving and Day 1996; Bell [undated]; Bell et al. 1998; Cluer and Hammack 1999).

6.2 Objectives And Management Actions

This section describes background, role in recovery, and site-specific objectives and management actions for each of the 16 floodplain sites in the Split Mountain to Desolation Canyon reach (summarized in Table 6-2). The sites are ordered in a downstream direction starting with the site nearest Split Mountain. Portions of river guide maps (Evans and Belknap 1996) and aerial photos are provided for each site. River miles on maps are the distance upstream from Green River, Utah; the Colorado River confluence is 120 miles further downstream of Green River. Success criteria; uncertainties, risks, and contingencies; research needs; and costs are presented and discussed for the 16 sites in section 7.0. Site-specific objectives and management actions are not provided for Labyrinth and Stillwater Canyons or for Gray Canyon to Labyrinth Canyon. These reaches are not currently considered priority in recovery of razorback sucker and bonytail. Floodplains in these canyons are usually perched, shallow basins with little potential of flooding, and may require mechanical reconstruction, but many are located within Canyonlands National Park and are difficult to access.

Table 6-1. Acres of inundation at 13,000 and 18,600 cfs and summary of previous actions on 16 floodplain sites in the Split Mountain to Desolation Canyon Reach of the Green River Subbasin. <levee or internal dike was breached>; (floodable area if levee is breached).

Floodplain Site	Acres of Inundation at cfs		Previous Actions
	13,000	18,600	
1. Thunder Ranch	0	(330)	Easement: 455.1 acres of land acquired 10/03; $700,000
2. IMC	0	4	Easement: 12 acres of land acquired; $10,000
3. Stewart Lake	<570>	570	Informal coordination with UDWR, Reclamation, Service initiated 2001
4. Sportsman's Lake	0	132	Informal contact made with property owners and Uintah Sportsman's Club
5. Bonanza Bridge	<23>	28	4 down/upstream levee breaches 3/97, 4/2000; top @ 13,000 cfs
6. Richens/Slaugh	0	45	Easement: 78 acres of land acquired; $69,850
7. Horseshoe Bend	<17>	22	1 lateral levee breach 1,000 feet, 10/97; top @ 13,000 cfs
8. The Stirrup	<20>	28	1 downstream levee breach 3/97; top @ 13,000 cfs
9. Baeser Bend	<38>	47	1 lateral levee breach 10/97; top @ 13,000 cfs
10. Above Brennan	<41>	50	4 down/upstream levee breaches 10/97, 4/2000; top @ 13,000 cfs
11. Johnson Bottom	<146>	146	1 downstream levee breach 3/98; top @ 13,000 cfs; internal dikes breached; control gate and kettle installed
12. Leota Ponds	<1,016>	1,016	2 levee breaches 3/98; top @ 12,500 cfs; internal dikes breached: units L-1 to L-10; control gate and kettle installed
13. Wyasket Lake	0 (304)	850	No action
14. Sheppard Bottom	0 (198)	35 (300)	Land fill for selenium remediation
15a. Old Charlie–Main	336	336	Inlet gate; outlet control gate and kettle installed
15b. Old Charlie–Diked	<56>	81	1 levee breached 3/97; topped at 13,000 cfs
16. Lamb Property	0	463	Easement on 463 acres; $112,000
Total Existing (Potential Additional):	2,263 (502)	3,853 (630)	

6.2.1 Thunder Ranch (RM 305.5)

Background. Thunder (Escalante) Ranch is located on the east bank of the Green River 4–5 miles upstream of the U.S. Highway 40 bridge near Jensen, Utah (Figure 6-1). Thunder Ranch is privately owned, and the Recovery Program has a perpetual easement on floodplain portions of the property. Thunder Ranch floodplain includes a depression with potential inundation area of about 330 acres. Thunder Ranch is the closest floodplain depression downstream of the known spawning bar for razorback sucker in the Green River, about 5 miles. Natural and manmade levees separating the floodplain depression from the river are topped at about 30,000 cfs. The floodplain is at an elevation where a river flow of about 16,900 cfs is needed for inundation (Flo Engineering 1997; Tetra Tech 2002). A central dike divides the floodplain internally into two ponds which hold water year-around. The dike is deteriorated and the two ponds are connected. A high selenium level is reported in springs and seeps from agricultural runoff that can drain into the floodplain.

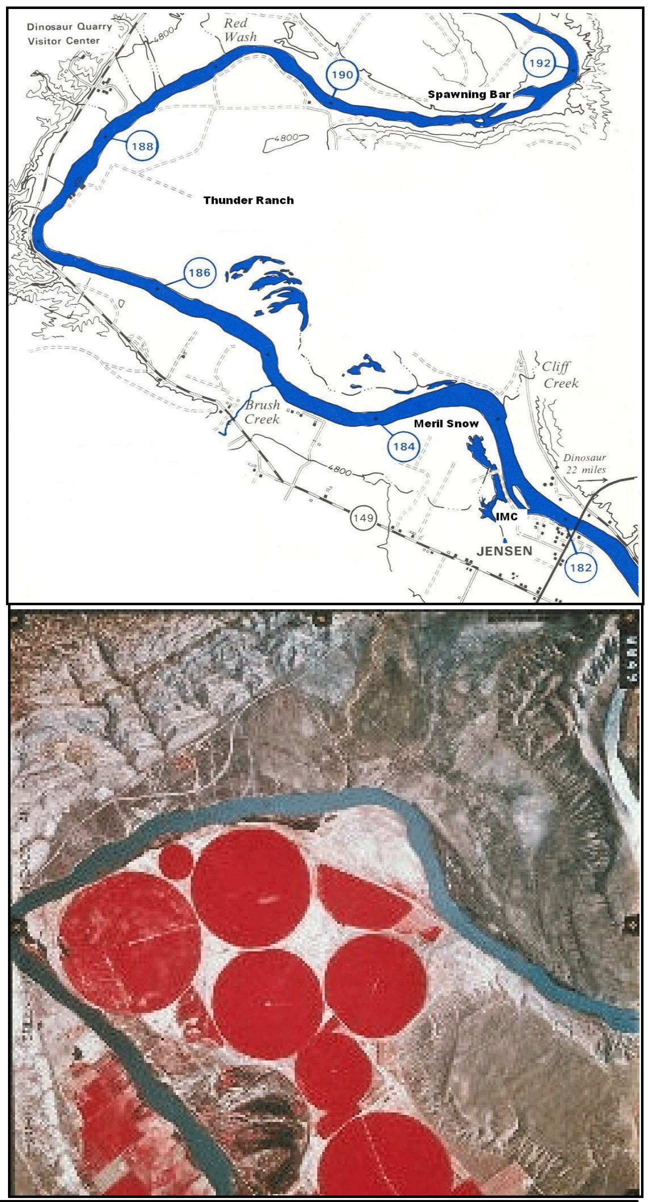


Figure 6-1. Map and aerial photo of the Thunder Ranch floodplain (photo bottom center).

Role In Recovery. Restoration of the Thunder Ranch floodplain is a priority of this Plan. The Thunder Ranch floodplain is an important potential nursery for razorback sucker. It is only 5 miles downstream from the known spawning bar, and the number of larvae potentially entrained is 76% greater with than without Thunder Ranch (see Appendix B: Floodplain Model Simulation #1; Table B-3). If 0.5% of entrained larvae survive to recruit as adults, the estimated number of adults produced in the Split Mountain to Desolation Canyon reach with and without Thunder Ranch is 2,979 and 1,695, respectively, for a net difference of 1,284 adults recruited to the population. Thunder Ranch floodplain could account for about 74% of annual recruitment necessary (i.e., 1,740) to maintain a self-sustaining population of 5,800 razorback sucker (i.e., 1,284/1,740 = 0.74).

Objectives And Management Actions

Objective 1-1. Restore inundation of the floodplain.

The Thunder Ranch floodplain currently floods at high river flows of about 30,000 cfs, and fish can become stranded for long time periods with infrequent reflooding. The levee that separates this floodplain from the main channel needs to be modified to allow flooding, larval entrainment, overwintering of fish, and escapement of fish to the main channel. This floodplain can provide substantial production of razorback sucker for species recovery if properly designed and managed.

✔ **Management Action 1-1A. Modify levee for maximum flooding, entrainment of larvae, and overwintering of fish.**

The levee that separates the Thunder Ranch floodplain from the Green River has been surveyed for elevation and a strategy for maximum flooding has been identified as a series of eight levee breaches to flood at about 16,900 cfs (Flo Engineering 1997; Tetra Tech 2002). Multiple breaches are likely to entrain more larvae than a single breach, but preclude controlled inflow and especially outflow of water. Strategic locations of levee breaches should be assessed for maximum flooding, larval entrainment, and fish survival. This action is to be implemented in 2004.

Objective 1-2. Reduce detrimental effects of selenium.

✔ **Management Action 1-2A. Implement selenium remediation.**

Remediation should be implemented to minimize effects of selenium on fish in the floodplain. Selenium in the Thunder Ranch floodplain is concentrated in springs and seeps from agricultural runoff, which can be piped or otherwise diverted from the floodplain. Other remediation measures may be possible.

Objective 1-3. Evaluate floodplain effectiveness.

✔ **Management Action 1-3A. Evaluate larval drift and entrainment.**

Larval entrainment should be maximized through levee modification described in Management Actions 1-1A. Larval entrainment should be evaluated at the Thunder Ranch floodplain. When available, large numbers of razorback sucker larvae and/or surrogate particles (e.g., beads) should be released in the river at the spawning bar and immediately upstream of Thunder Ranch to assess entrainment of wild fish. This information should be assimilated into a Comprehensive Larval Drift Report.

✔ **Management Action 1-3B. Evaluate growth and survival of razorback sucker.**

Studies of growth and survival of hatchery razorback sucker should be performed at the Thunder Ranch floodplain to determine: (1) monthly growth and survival, (2) suitable densities of razorback sucker for maximum growth and survival, (3) adequacy of water quality over long time periods (e.g., 12–24 months), and (4) growth and survival with varying densities of nonnative fishes. Fish used for these studies can be released in the floodplain to augment the wild population. This information should be assimilated into a Comprehensive Growth/Survival Report.

✔ **Management Action 1-3C. Assess effectiveness of management actions.**

The effectiveness of the Thunder Ranch floodplain as a nursery for razorback sucker should be evaluated. This evaluation should include, but not be limited to: frequency and duration of flooding, retention of suitable water quantity and quality, growth and survival of young fish, and reconnection and escapement by fish to the main channel. Eight levee breaches will be excavated in 2004 to maximize inundation and larval entrainment during spring runoff, at 16,900 cfs and higher. If it is determined that these levee breaches are not sufficient for the desired degree of river inundation, larval entrainment, fish escapement, and desiccation, alternative actions may be considered, including inlet and outlet gates for complete floodplain desiccation and resetting.

6.2. 2 IMC (RM 302.5)

Background. The IMC floodplain is a large backwater located on the west bank of the Green River about 0.5 miles upstream of the U.S. Highway 40 bridge near Jensen, Utah (Figure 6-2). The backwater is on private property (Intermountain Concrete Company) and the Recovery Program has an easement for access, flooding, and management. This backwater fills and drains with river elevation like a terrace floodplain. Inundation area for the IMC floodplain, based on survey data, is 0–3.4, 10.5, and 13.4 acres at 18,000; 20,300; and 24,000 cfs, respectively (Flo Engineering 1997).

Role In Recovery. This site has limited value as a nursery, but could provide feeding and resting habitat for adult and large juvenile razorback sucker, bonytail, and Colorado pikeminnow during spring runoff. The floodplain is only 8 miles downstream of the razorback sucker spawning bar and larval entrainment may be substantial, but retention is probably short-term given the terraced nature of the site. The IMC site is located immediately downstream of the Meril Snow property, for which the Recovery Program was unsuccessful in acquiring an easement. The value of this site may be in the long-term ecological value as habitat for adults and juveniles of native fishes and as a nutrient source for the mainstem.

Objectives And Management Actions

Objective 2-1. Protect the IMC backwater from man-made changes.

The current easement agreement with the landowner precludes modifications to the site without conference and approval from the Recovery Program. This ensures protection of the site from modifications that could reduce the value of the overall Green River riparian ecosystem.

✔ **Management Action 2-1A. Coordinate with landowner to ensure protection of IMC backwater.**

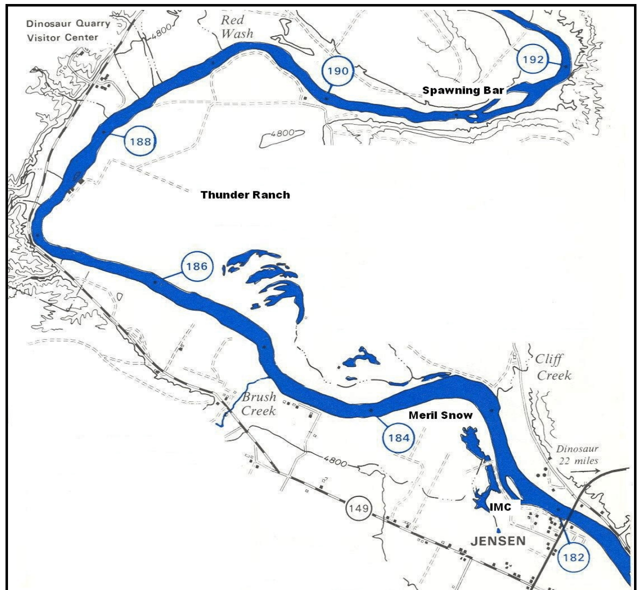


Figure 6-2. Map of the IMC backwater.

No specific management actions are recommended for the IMC backwater, except protection from man-made changes, including filling, reshaping, draining, or other activities not consistent with the easement agreement. The potential for this site as a nursery is probably minimal because of the small area of inundation, its terraced nature, and possible high cost of reconstruction to convert the site to a floodplain depression. The site may be re-evaluated at a later date if recovery criteria are not achieved with ongoing actions.

6.2.3 Stewart Lake (RM 300)

Background. Stewart Lake is an approximately 570-acre diked depression located on the west bank of the Green River 2 miles downstream of the U.S. Highway 40 bridge near Jensen, Utah (Figure 6-3). The lake is the principal feature of the Stewart Lake Waterfowl Management Area. It is managed by the UDWR for waterfowl, wildlife, and recreation as part of wetlands mitigation for the construction of Flaming Gorge Dam in 1962. The lake is used by waterfowl hunters in fall and winter.

High concentrations of selenium have been reported from Stewart Lake sediments, water, aquatic organisms, and waterfowl, and there is concern over its effect on reproduction and health of razorback sucker (Hamilton and Waddell 1994; Hamilton 1998; Hamilton et al. 2001a; Hamilton et al. 2001b). Reclamation has implemented a remediation program that includes several structural modifications to Stewart Lake to reduce selenium levels, including soil aeration, inlet and outlet water control gates, "Texas crossings" to allow emergency draining from the lake at high water elevations, construction of a network of canals for enhanced draining, and seasonal filling and draining of the lake. A tile drainage system is being installed at the upper end of Stewart Lake in 2004 to allow for diversion of selenium-laden water directly to the

Green River for dilution. An inlet has also been constructed from nearby Brush Creek to import fresh water to the lake. These combined remediation measures, together with proper water management, will reduce the concentration of selenium and could make the site suitable as a nursery and rearing area for razorback sucker. The river flows into the inlet gate at Stewart Lake at about 7,500 cfs.

<u>Role In Recovery</u>. Stewart Lake is an important potential nursery for razorback sucker. It is about 11 miles downstream of the known spawning bar and larval entrainment could be significant if inflows are strategically located (Table B-2). The lake can hold water year-around, and is connected to the Green River by two gated canals that control water in and out of the lake at the upstream and downstream ends, respectively. This water control system could be managed to inundate the lake for extended periods, then drained to provide timed escape of fish to the main channel and control of nonnative fishes through floodplain desiccation.

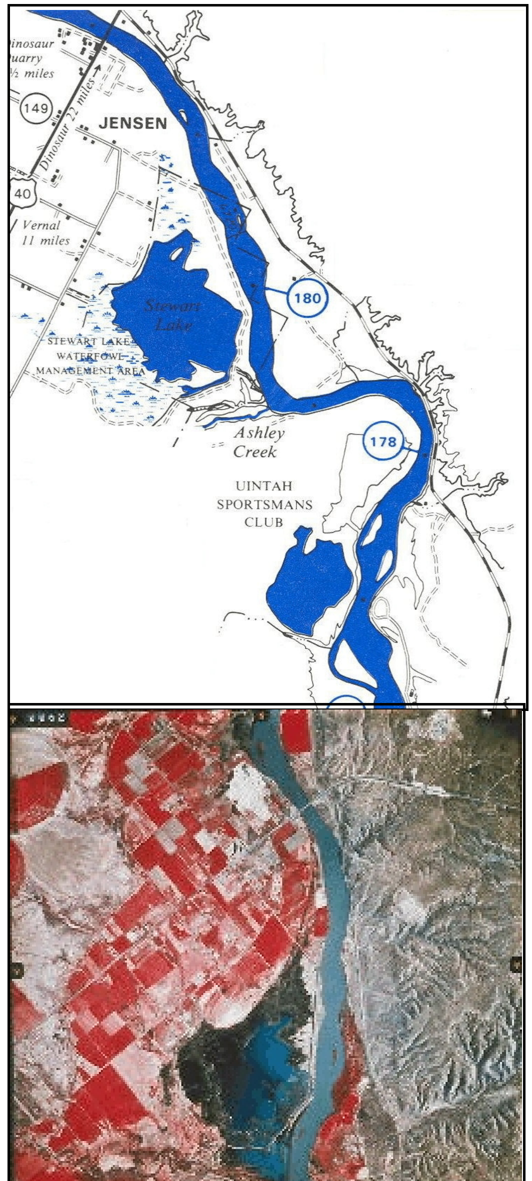


Figure 6-3. Map and aerial photo of Stewart Lake (photo bottom center).

<u>Objectives And Management Actions</u>

Objective 3-1. Coordinate management of Stewart Lake.

Stewart Lake is managed by the UDWR as the Stewart Lake Waterfowl Management Area, and Reclamation, and the Service are assisting with selenium remediation. The Recovery Program should coordinate with these agencies to identify best management strategies to benefit razorback sucker and not negatively impact the primary purpose of the waterfowl management area.

✔ **Management Action 3-1A. <u>Coordinate management of Stewart Lake with UDWR, Reclamation, and the Service</u>.**

Stewart Lake currently has a structural design that provides considerable flexibility in water management. The site is a flattened, shallow depression with inlet and outlet water control gates and a canal system that allows most of the lake to drain. Current selenium remediation includes filling the lake with river inflow in spring and draining it in late summer to flush selenium. Water is allowed into the lake in fall and left over winter for waterfowl habitat and hunting. This water management strategy allows the lake to remain flooded for only 3–4 months following spring runoff. This strategy would need to be modified to provide inundation for a longer time period for young razorback sucker to reach a suitable size before escaping to the main channel. Studies indicate that razorback sucker must be over 90 mm TL (about 6 months old) and preferably over 230 mm TL (about 17 months old) to survive in the main channel.

✔ **Management Action 3-1B. Evaluate selenium remediation.**

Reclamation and the Service are currently assisting UDWR with remediation of selenium in Stewart Lake. Structural modifications, including inlet and outlet water control gates, Texas crossings, and a trenched drainage system, together with frequent drainage of the lake, have reduced selenium concentration. A tile collector system will be installed by Reclamation and evaluated by the Service in 2004 to further reduce selenium concentration and allow for longer retention of water. This evaluation is the responsibility of the Service and Reclamation, and the Recovery Program should coordinate future management once acceptable selenium concentrations are achieved. The Recovery Program should hold hatchery-reared razorback sucker and bonytail in Stewart Lake to assess growth and survival following remediation.

Objective 3-2. Evaluate floodplain effectiveness.

Stewart Lake should be managed to retain water as long as possible to allow for growth of razorback sucker before escaping to the river. A period of 12–24 months is the most desireable.

✔ **Management Action 3-2A. Evaluate larval drift and entrainment.**

Stewart Lake is currently the first major accessible floodplain downstream of the razorback sucker spawning bar. Wild larvae, juveniles, and adult razorback sucker have been recently found in Stewart Lake and its outflow, indicating historic and recent fish use. Stewart Lake can be a critical floodplain site to assist recovery of razorback sucker, if properly managed. When available, large numbers of razorback sucker larvae and/or surrogate particles (e.g., beads) should be released in the river immediately upstream of Stewart Lake to assess entrainment of wild fish. This information should be assimilated into a Comprehensive Larval Drift Report.

✔ **Management Action 3-2B. Evaluate growth and survival of razorback sucker.**

Studies of growth and survival of hatchery razorback sucker should be performed at Stewart Lake to determine: (1) monthly growth and survival, (2) suitable densities of razorback sucker for maximum growth and survival, (3) adequacy of water quality over long time periods (e.g., 12–24 months), and (4) growth and survival with varying densities of nonnative fishes. Fish used for these studies can be released in the floodplain to augment the wild population. This information should be assimilated into a Comprehensive Growth/Survival Report

✔ **Management Action 3-2C. Assess effectiveness of management actions.**

Maximum larval entrainment at Stewart Lake is important for this site to function as a nursery for razorback sucker. Water currently enters Stewart Lake primarily through one narrow gated canal (about 30 feet wide) that may not entrain large numbers of larvae. Water is currently allowed to enter the floodplain until it is full, but it may be possible to allow flow-through to increase larval entrainment. Flow and entrainment characteristics should be assessed to determine if structural modification to the inlet canal is necessary (e.g., widen the inlet canal).

Best management strategy for razorback sucker recovery in Stewart Lake is to allow flow-through during spring runoff (to entrain drifting larvae), close the inlet and outlet gates, and allow water to remain in the lake for approximately 14 months until the following August when the lake would be drained to evacuate the fish. This strategy should be evaluated to determine if razorback sucker will grow to sufficient size to escape and survive in the main river. Spring flows would be allowed into the lake in the second year to refresh the lake water and stimulate production. This would allow the lake to inundate and drain to flush selenium on a 14-month schedule, rather than on a 3-month schedule. Control gates currently allow water to be retained or completely drained from Stewart Lake, which could be used to allow escapement of young razorback sucker and control of nonnatives. Management actions should be approved by and coordinated with UDWR to insure that objectives of the Stewart Lake Waterfowl Management Area are not compromised.

6.2.4 Sportsman's Lake (RM 297)

Background. Sportsman's Lake is located on the west bank of the Green River 3 miles downstream of Stewart Lake (Figure 6-4). Sportsman's Lake is also known as Little Stewart Lake. It is located on private property and is managed by the local Uintah Sportsman's Club primarily for waterfowl hunting. The lake holds water year-around and approximately 132 acres are inundated by the Green River at flows of about 20,000 cfs (Irving and Burdick 1995). Sportsman's Lake is connected to the Green River through a single canal that is gated to control water inflow and release. The levee that separates Sportsman's Lake from the Green River is high and wide and is topped only by high flood events. However, the river can top a levee about 0.5 miles upstream of the lake at high flows allowing a large area in and around the lake to become inundated.

Role In Recovery. Sportsman's Lake currently has limited value as a nursery or rearing area for razorback sucker, except perhaps at high river flows when a large area in and around the lake becomes inundated. The inlet canal to Sportsman's Lake is long and narrow, and entrainment of larvae and fish access is probably limited. Wild razorback sucker larvae may become naturally entrained and rear in Sportsman's Lake and provide overall benefit to species recovery. However, no specific management actions are recommended for this site because of its distance from the river, limited inflow and entrainment capability, current private ownership, and high potential costs for modifying the site to function as a reset depression floodplain.

Objectives and Management Actions

Objective 4-1. Coordinate possible future management of Sportsman's Lake.

The Recovery Program should establish contact with the property owners and Uintah Sportsman's Club to evaluate the prospect of Sportsman's Lake for possible future recovery actions.

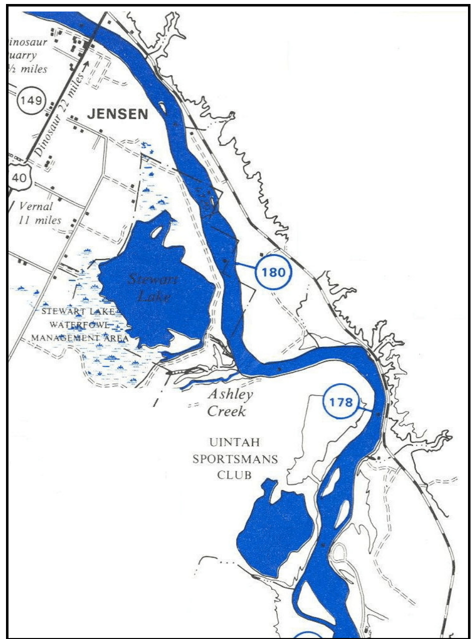


Figure 6-4. Map of Sportsman's Lake.

✔ **Management Action 4-1A. <u>Coordinate with property owners and Uintah Sportsman's Club for possible future use of Sportsman's Lake, if necessary.</u>**

No specific management actions are recommended for Sportsman's Lake at this time. However, this site is located only 14 miles downstream of the razorback sucker spawning bar and could be a valuable site for future use as a contingency to other floodplain sites that may not succeed. The Recovery Program has contacted the land owners of Sportsman's Lake and they have indicated an interest in negotiating a future easement. The site may be re-evaluated at a later date if recovery criteria are not being achieved with ongoing management actions.

6.2.5 Bonanza Bridge (RM 289.5)

Background. The Bonanza Bridge floodplain is located on the southeast bank of the Green River immediately downstream of the State Highway 40 bridge to Bonanza, Utah, on lands administered by Bureau of Land Management (BLM) (Figure 6-5). The Bonanza Bridge floodplain is separated from the Green River by large natural levees and is formed as two depressions; one low and one perched. Seepage from the Green River partially fills the low depression, but the floodplain does not hold water year-around in dry years, such as 2001 and 2002. This site overwintered fish during a wet cycle in the 1990's and probably holds water year-around in most wet years. The floodplain has riparian vegetation, tamarisk, scrub oak, and cottonwoods; good cottonwood regeneration was noted following levee breaches (Personal Communication, Kevin Christopherson, UDWR). Prior to levee breaches, the natural levee was topped at about 19,700 cfs, and the area of inundation was approximately 38 acres at Green River flows of 24,000 cfs. A 350-foot cut was made at the downstream end of the levee in 1997 to allow 23, 26, 28, 30, and 38 acres to flood at 13,000; 15,000; 18,000; 20,300; and 24,000 cfs, respectively (Figure 6-6; Flo Engineering 1997). Three additional upstream breaches were excavated in April 2000 to improve larval entrainment, but the effectiveness of these breaches could not be evaluated because of low spring flows in 2001 and 2002. River flows have reconfigured these breaches and inundation levels may have changed from original surveys.

Role In Recovery. The Bonanza Bridge floodplain could be an important nursery for razorback sucker, as well as habitat for large juvenile and adult razorback sucker, bonytail, and Colorado pikeminnow during spring runoff. The floodplain is about 21 miles downstream of the known spawning bar for razorback sucker, and larval entrainment could be substantial if levee breaches are effective. The Bonanza Bridge floodplain could serve as a long-term nursery for razorback sucker and contribute to recruitment of adults during wet years, but is not likely to overwinter fish in dry years. The Bonanza Bridge floodplain has served as a principal site to evaluate growth, survival, and recruitment of hatchery razorback sucker and bonytail as part of population augmentation. Knowledge gained from this research is important to understanding stocking strategies of hatchery fish.

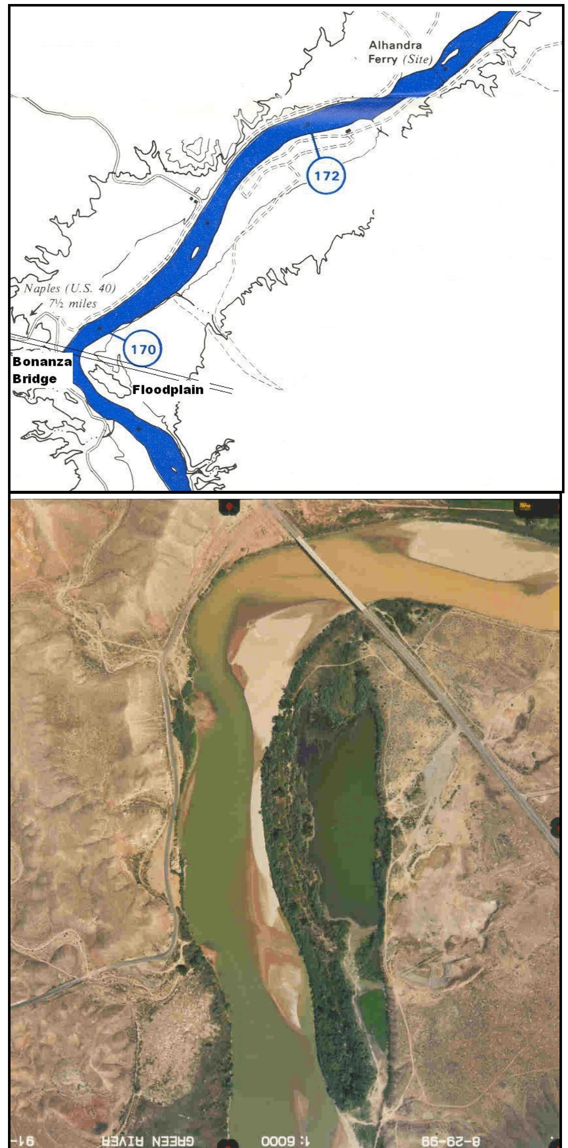


Figure 6-5. Map and aerial photo of the Bonanza Bridge floodplain (photo right center).

Objectives And Management Actions

Objective 5-1. Evaluate floodplain effectiveness.

The Bonanza Bridge floodplain may function as a 12–month nursery during wet years when ground water is sufficient to maintain water year-around in the floodplain. This temporal aspect of the Bonanza Bridge floodplain should be observed to determine if this site is valuable principally during wet years. Actions taken by the Recovery Program to maximize entrainment through upstream and downstream levee breaches should be evaluated for effectiveness. No construction actions are recommended for this site beyond prior levee modification because of the small area of inundation.

✔ **Management Action 5-1A. <u>Monitor/evaluate effectiveness of levee breaches to entrain and retain water at various river stages</u>.**

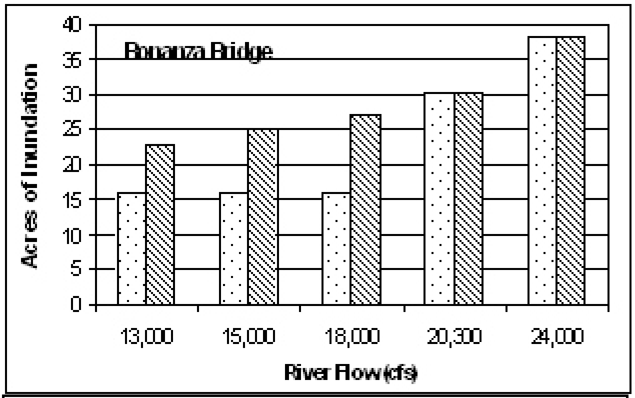


Figure 6-6. Relationship of Green River flow to acres of flooded bottomland at the Bonanza Bridge site with (light) and without (dark) levees.

The levee that separates Bonanza Bridge floodplain from the main river channel was breached at the downstream end in 1997 and at the upstream end in 2000. The effectiveness of these levee breaches should be evaluated to determine if this strategy works for entraining larvae. Further modification may be necessary if the levee breaches are substantially modified by channel dynamics, or if entrainment can be significantly increased. Flow characteristics at the Bonanza Bridge floodplain should be assessed to determine the combination of river flows and levee management at which larval entrainment is maximized. Preliminary results of a drift study in May 2003 using artificial beads (Personal Communication, Kevin Christopherson, UDWR) showed that the Bonanza Bridge floodplain had low water volume entering the site (23,088 cubic meters), but relatively high estimated bead entrainment (10,390), compared to the Above-Brennan floodplain (666,924 cubic meters and 2,668 beads). These preliminary results suggest that larval entrainment may not be a function of water entrainment, but may be related to floodplain location and local channel hydraulics.

✔ **Management Action 5-1B. <u>Periodically assess fish entrainment, growth, and survival</u>.**

The Bonanza Bridge floodplain is a small and readily accessible site that has been used to evaluate best strategies for maximizing growth, survival, and recruitment of hatchery razorback sucker and bonytail as part of the population augmentation program. Further assessment of growth and survival at this floodplain is not recommended until a synthesis of information is assimilated and interpreted in a Comprehensive Growth/Survival Report. The Bonanza Bridge floodplain will hold water year-around in moderately wet and wet years, and the site should be monitored to confirm that it will function as a 12–month reset floodplain. This floodplain may provide transient habitat for adult razorback sucker, bonytail, and Colorado pikeminnow during spring runoff.

6.2.6 Richens/Slaugh/Slaugh (RM 288)

Background. The Richens/Slaugh/Slaugh floodplain is located on the west bank of the Green River about 3 miles downstream of the State Highway 40 bridge to Bonanza, Utah, on property previously owned by three land owners; V. Richens, C. Slaugh, and D. Slaugh (Figure 6-7). The Recovery Program has acquired perpetual easements from the landowners to allow the property to flood about 45 acres at 18,600 cfs. This site is currently a shallow depression that functions as a terrace floodplain; hence, inundation and larval retention is short-term and entirely related to river stage.

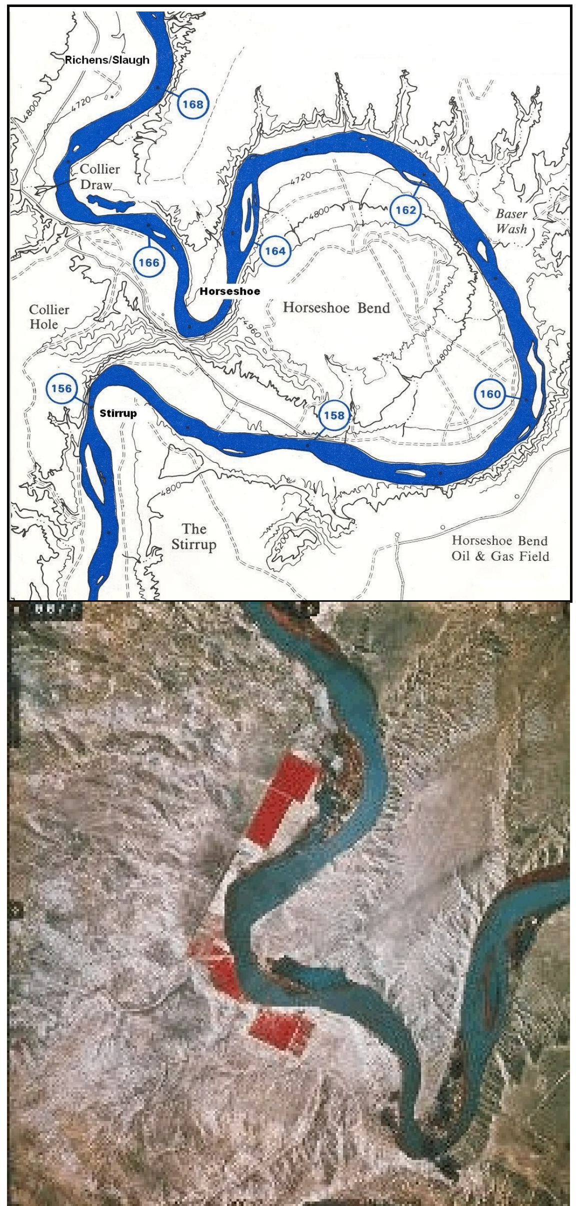


Figure 6-7. Map and aerial photo of the Richens/Slaugh/Slaugh floodplain (photo top center).

Role In Recovery. The immediate value of the Richens/Slaugh/Slaugh floodplain site is limited, and it currently functions as a terrace that fills and drains with river stage. The site is about 25 miles downstream of the razorback sucker spawning bar but larval retention is probably minimal because of its shallow, terraced nature. The potential cost of dike construction to protect adjacent properties and excavation is not currently justified, given the small area of potential inundation. The site may be re-evaluated at a later date if recovery criteria are not achieved with ongoing actions. This floodplain may have long-term ecological value as habitat for adults and juveniles and as a nutrient source for the mainstem. Further investment of funds by the Recovery Program at this site is not recommended at this time.

Objectives And Management Actions

Objective 6-1. Protect the Richens/Slaugh/Slaugh floodplain from man-made changes.

No specific management actions are recommended for the Richens/Slaugh/Slaugh floodplain, except protection from man-made changes, including filling, reshaping, draining, or other activities not consistent with the easement agreement with the Recovery Program.

✔ **Management Action 6-1A. <u>Coordinate with landowners to ensure protection of the Richens/Slaugh/Slaugh floodplain.</u>**

The current easement agreement with the landowner precludes modifications to the site without conference and approval from the Recovery Program. This ensures protection of the site from modifications that could reduce the value of the overall Green River riparian ecosystem.

6.2.7 Horseshoe Bend (RM 285)

***<u>Background</u>*.** The Horseshoe Bend floodplain is located on the east bank of the Green River about 5.5 miles downstream of the State Highway 40 bridge to Bonanza, Utah, on lands administered by BLM (Figure 6-8). The Horseshoe Bend floodplain has high natural levees thick with vegetation of scrub oak, tamarisk, Russian olive, and cottonwoods. This site was originally classified as a terrace floodplain, but it has a shallow depression that holds water for short time periods. Water seeps into this floodplain before river surface flow connection, but the floodplain dries seasonally after runoff. The levee was breached for about 1,000 feet at the downstream end between March 1997 and March 1998, and the area of inundation varies from about 17 acres at 13,000 cfs to 48 acres at 24,000 cfs (Figure 6-9; Flo Engineering 1997). Flow into the site is good and a second upstream breach has not been excavated at Horseshoe Bend.

***<u>Role In Recovery</u>*.** The Horseshoe Bend floodplain may have limited value as a nursery for razorback sucker because it dries in most years. It may, however, have value as habitat during spring runoff for adult razorback sucker, bonytail, and Colorado pikeminnow. This site is about 27 miles downstream of the known spawning bar for razorback sucker, and larval entrainment is likely significant, given the width of the levee breach, but retention is low because it drains with river stage. This floodplain traps water for short time periods and generally becomes desiccated in the first summer following inundation. Entrained larvae would likely not survive more than a few months except perhaps in wet years. Further modifications to enhance larval entrainment at this site are not recommended at this time, but

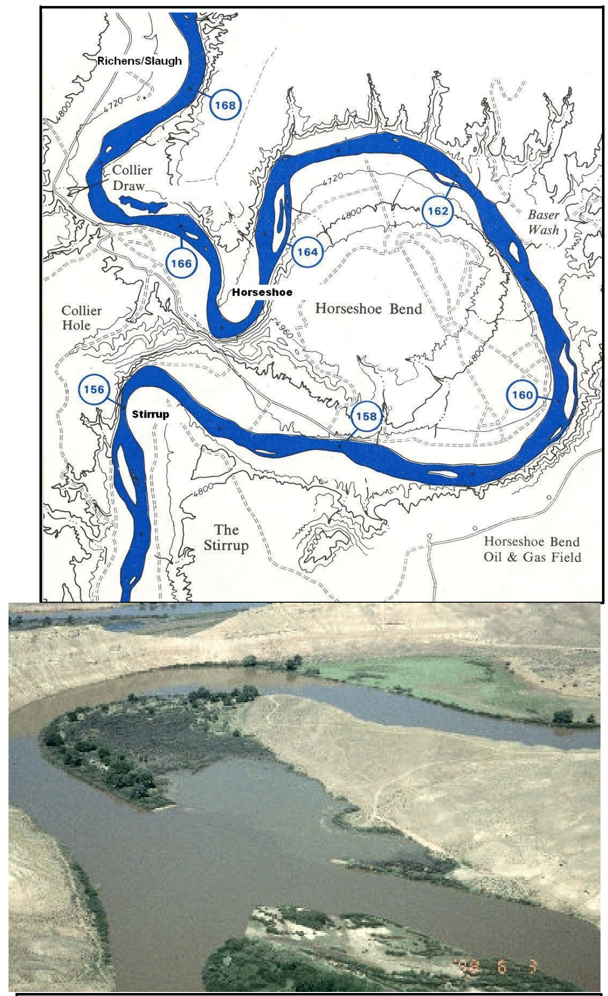


Figure 6-8. Map and aerial photo of the Horseshoe Bend floodplain (photo center).

basin excavation to enhance retention may be desirable and possible. Twelve adult Colorado pikeminnow were captured in this floodplain during runoff in 1999, confirming that floodplains are used by this species (Personal Communication, Kevin Christopherson, UDWR); the absence of carcasses in these drying depressions suggests that these adults successfully escape to the river before these depressions become isolated.

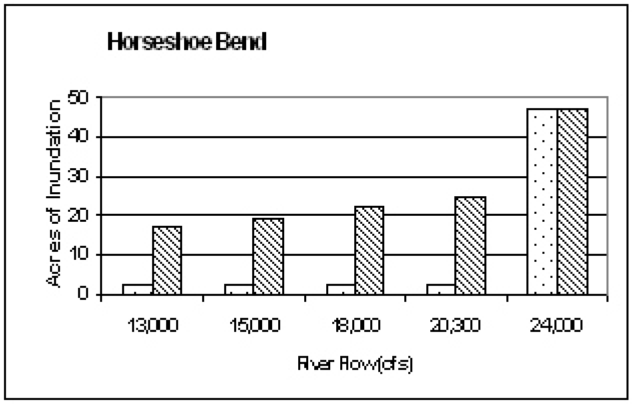


Figure 6-9. Relationship of Green River flow to acres of flooded bottomland at the Horseshoe Bend site with (light) and without (dark) levees.

Objectives And Management Actions

Objective 7-1. Restructure floodplain, if necessary.

The Horseshoe Bend floodplain does not hold water year-around, but the basin could be excavated to extend larval retention time. Further restoration of this floodplain may be necessary if other management actions are not effective at restoring floodplain habitat and establishing and maintaining a population of razorback sucker.

✔ **Management Action 7-1A. Modify levee and excavate basin, if necessary.**

The Horseshoe Bend floodplain has a single 1,000-foot levee breach at the downstream end with no control gate. It becomes inundated when the river reaches the level of the breach, about 13,000 cfs. This floodplain does not hold water year-around in dry years, or perhaps even in average or moderately wet years. Entrained larvae would either have to leave the site within 1–2 weeks with receding flows or become stranded and die. This site is not likely to function as a 12 or 24-month nursery without substantial excavation and reconstruction. This floodplain may naturally produce fish during wet years, and should be allowed to inundate through the single breach. Because it drains and desiccates regularly, it does not provide a long-term refuge for nonnative fishes. No further Recovery Program activity is recommended for this site at this time, although further restoration may be necessary if other management actions are ineffective.

Objective 7-2. Evaluate floodplain effectiveness.

✔ **Management Action 7-2A. Implement and evaluate management actions, as necessary.**

The Horseshoe Bend floodplain should be visited and evaluated annually to determine if the site is successfully entraining water and how long it retains water with given runoff years. This action is an annual cursory evaluation of the site to insure that the levee breach is remaining open and is effective, and to assess the potential and need for future basin excavation.

6.2.8 The Stirrup (RM 276)

Background. The Stirrup floodplain is located on the east bank of the Green River about 14 miles downstream of the State Highway 40 bridge to Bonanza, Utah, on lands administered by BLM (Figure 6-10). The Stirrup floodplain has high natural levees thick with vegetation of scrub oak, tamarisk, and a few large cottonwoods. A natural drainage swale exists at the lower end of the floodplain that is lined by large debris. Pre-flooding occurs from seepage through the levee, and the floodplain drains as flow recedes, but it can hold water for a year and fish have survived over winter. The levee was breached at the downstream end in March 1997, and the area of inundation is about 20 acres at 13,000 cfs and 28 acres at 18,600 cfs (Figure 6-11; Flo Engineering 1997). The Stirrup floodplain has a deposit of gravel/cobble that is unusual for floodplain depressions, but could serve as a spawning site for razorback sucker and bonytail. Spawning has been documented for these species in similar floodplains of the lower Colorado River basin (Mueller et al. 2002; Mueller 2003) and in hatchery ponds at Dexter National Fish Hatchery (Hamman 1987). Studies of growth and survival of hatchery razorback sucker have been conducted at the Stirrup floodplain (Christopherson and Birchell 2002; Birchell and Christopherson 2002), and studies in 2002–2003 evaluated these parameters under various densities of nonnative fishes.

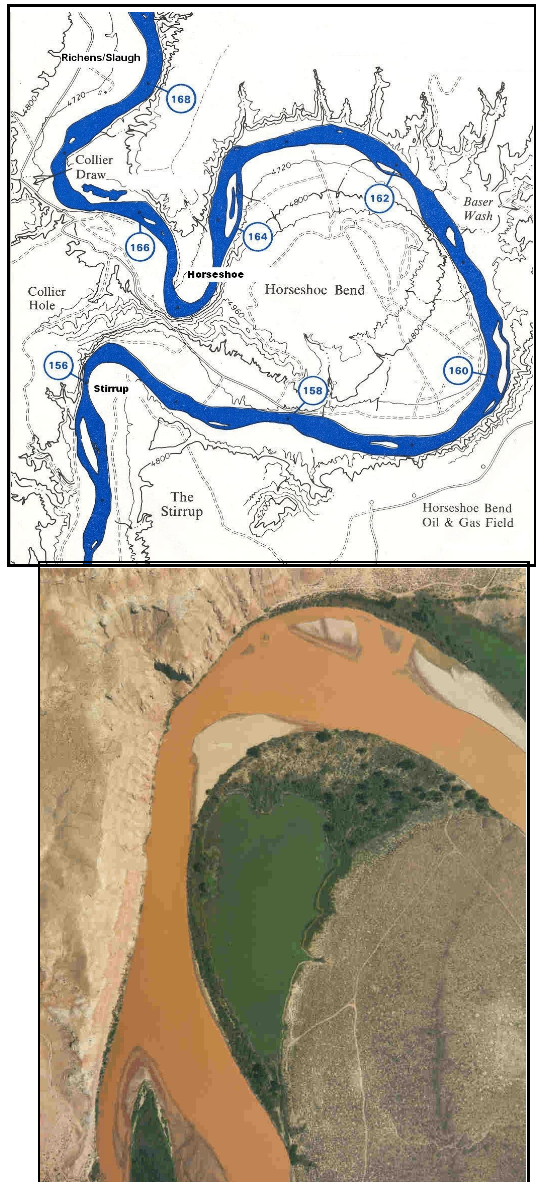


Figure 6-10. Map and aerial photo of the Stirrup floodplain (photo center).

Role In Recovery. The Stirrup floodplain is potentially an important nursery habitat for razorback sucker. It is about 36 miles downstream of the known spawning bar for razorback sucker, and although number of drifting larvae is reduced with distance from the spawning bar, numbers entrained in the Stirrup floodplain may be sufficient to produce recruitable size fish (Table B-2). Expansion of the razorback sucker population may also result in additional spawning sites. Potential spawning bars exist 4–6 miles upstream of the Stirrup, based on captures of wild and hatchery adult razorback sucker (Valdez and Masslich 1989; Tyus and Karp 1990). The Stirrup floodplain is an ideal site for experimentation and studies of growth, survival, and size of escape to the main river. It is small and easily managed with a single narrow breach.

Objectives And Management Actions

Objective 8-1. Evaluate floodplain effectiveness.

The Stirrup floodplain typically holds water year-around and could function as a 12 or 24–month nursery. Actions taken by the Recovery Program to maximize entrainment through a downstream levee breach should be evaluated for effectiveness. No further construction actions are recommended for this site beyond prior levee modification because of the small area inundated.

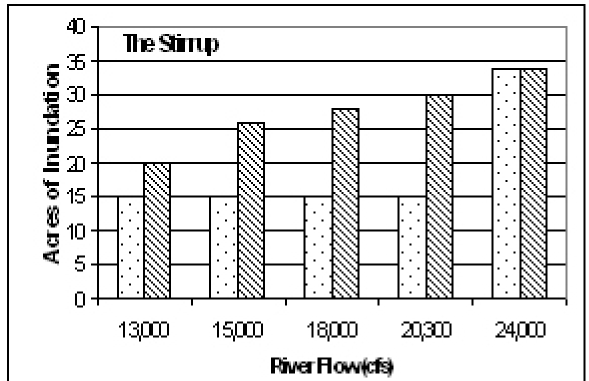


Figure 6-11. Relationship of Green River flow to acres of flooded bottomland at the Stirrup site with (dark) and without (light) levee breaches.

✔ **Management Action 8-1A. Monitor/evaluate effectiveness of levee breach to entrain and retain water at various river stages.**

The levee that separates the Stirrup floodplain from the main river channel was breached at the downstream end in 1997. The effectiveness of the levee breach should be evaluated to determine if this strategy works for entraining larvae. Further modification may be necessary if the levee breach is substantially modified by channel dynamics, or if entrainment can be significantly increased. Flow characteristics at the Stirrup floodplain should be assessed to determine the combination of river flows and levee management at which larval entrainment is maximized.

✔ **Management Action 8-1B. Periodically assess fish entrainment, growth, and survival.**

The Stirrup floodplain is a small and readily accessible site that has been used to evaluate best strategies for maximizing growth, survival, and recruitment of razorback sucker and bonytail as part of the population augmentation program. Further assessment of growth and survival at this floodplain is not recommended until a synthesis of information is assimilated and interpreted in a Comprehensive Growth/Survival Report. The Stirrup floodplain should be allowed to inundate with spring runoff. This requires no active management, except monitoring of breaches and inundation to ensure that the floodplain depression is functioning properly. Levee and breach reconstruction may be necessary if the floodplain is not functioning as a 12 or 24–month reset floodplain, although no additional active management is recommended at this time.

It is hypothesized that bonytail will benefit from a greater availability of floodplain habitat, and actions described in this Plan will assist establishment of a wild bonytail population in the Green River Subbasin. Where possible and feasible, Recovery Program activities to evaluate effectiveness of floodplain management to benefit razorback sucker should also evaluate benefits to bonytail. The Stirrup floodplain is one of several sites that can be used to evaluate growth and survival of bonytail.

6.2.9 Baeser Bend (RM 273)

Background. The Baeser Bend floodplain is located on the east bank of the Green River about 15 miles downstream of the State Highway 40 bridge to Bonanza, Utah, on lands administered by BLM (Figure 6-12). The Baeser Bend floodplain is separated from the Green River by a high, heavily vegetated natural levee. The levee has upland vegetation and several large cottonwoods and the bottomland has a large open area in the deeper center, surrounded by a wide band of thick cattails, reeds, and Russian olive. The floodplain receives water through seepage and drains as river flow recedes, although it may retain enough water to sustain fish over winter. The area of inundation was 60 acres at 24,000 cfs before the levee was breached laterally in 1997. This breach allows the floodplain to inundate 38 acres at 13,000 cfs and 47 acres at 18,600 cfs (Figure 6-13; Flo Engineering 1997). This breach currently functions well and provides good water entrainment and circulation for this floodplain (Personal Communication, Kevin Christopherson, UDWR). Studies of growth and survival of hatchery fish were conducted at this site during 2003.

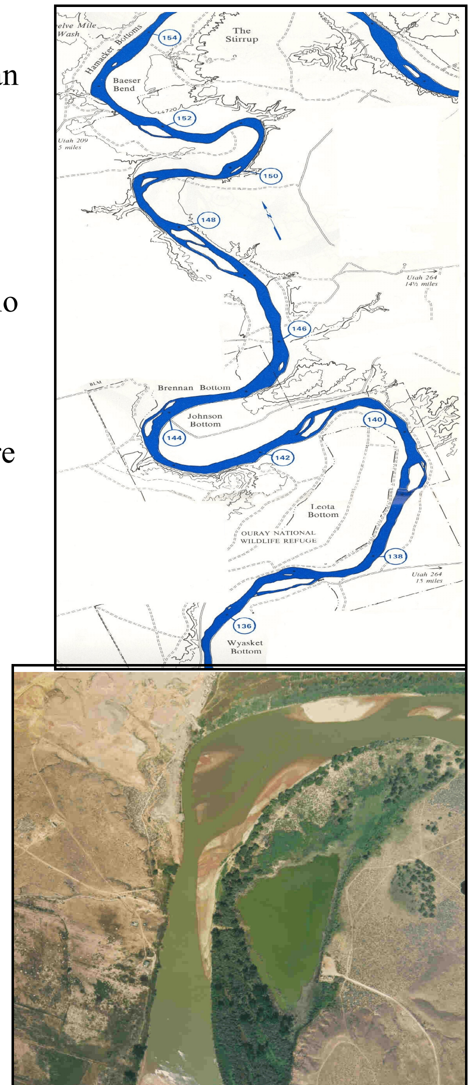


Figure 6-12. Map and aerial photo of the Baeser Bend floodplain (photo right center).

Role In Recovery. The Baeser Bend floodplain is potentially an important nursery for razorback sucker. It is about 38 miles downstream of the known spawning bar for razorback sucker, and numbers of entrained larvae may be low because of distance from the spawning bar and a single 20-foot wide breach (Table B-2). Expansion of the razorback sucker population may result in additional spawning sites. Potential spawning bars exist 6–8 miles upstream of this site, based on captures of wild and hatchery adult razorback sucker (Valdez and Masslich 1989; Tyus and Karp 1990).

Objectives And Management Actions

Objective 9-1. Evaluate floodplain effectiveness.

The Baeser Bend floodplain holds water year-around in all but dry years and could function as a 12 or 24-month nursery. Actions taken by the Recovery Program to maximize entrainment through a levee breach should be evaluated for effectiveness. No further construction actions are recommended for this site beyond prior levee modification because of the small area inundated.

✔ **Management Action 9-1A. Monitor/evaluate effectiveness of levee breach to entrain and retain water at various river stages.**

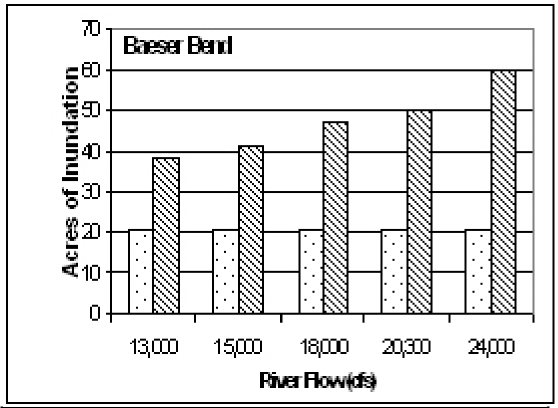


Figure 6-13. Relationship of Green River flow to acres of flooded bottomland at the Baeser Bend site with (light) and without (dark) levees.

The levee that separates Baeser Bend floodplain from the main river channel was breached in 1997. The effectiveness of this levee breach should be evaluated to determine if this strategy works for entraining larvae. Further modification may be necessary if the levee breach is substantially modified by channel dynamics, or if entrainment can be significantly increased. Flow characteristics at the Baeser Bend floodplain should be assessed to determine the combination of river flows and levee management at which larval entrainment is maximized.

✔ **Management Action 9-1B. Periodically assess fish entrainment, growth, and survival.**

The Baeser Bend floodplain is a small and readily accessible site that has been used to evaluate best strategies for maximizing growth, survival, and recruitment of razorback sucker and bonytail. Further assessment of growth and survival at this floodplain is not recommended until a synthesis of information is assimilated and interpreted in a Comprehensive Growth/Survival Report.

The Baeser Bend floodplain inundates at river flows of about 13,000–14,000 cfs, and holds water and fish year-around, except in dry years. This site could function as a natural 12 or 24–month nursery for razorback sucker. The Baeser Bend floodplain should be allowed to inundate with spring runoff. This requires no active management, except monitoring of breaches and inundation to ensure that the floodplain depression is functioning properly. Levee and breach reconstruction may be necessary if the floodplain is not functioning as a 12 or 24–month reset floodplain, although no additional active management is recommended at this time.

6.2.10 Above-Brennan (RM 269)

Background. The Above-Brennan floodplain is located on the east bank of the Green River about 21 miles downstream of the State Highway 40 bridge to Bonanza, Utah, on lands administered by BLM. The levee separating this floodplain from the river has a low spot and prior to restoration, it was topped at about 12,900 cfs. One downstream breach was excavated in October 1997 and three upstream breaches were excavated in April 2000 (Figure 6-14). An area of 41 acres inundates at 13,000 cfs, 50 acres at 18,600 cfs, and 63 acres at 24,000 cfs (Figure 6-15; Flo Engineering 1997). The floodplain has a large depression with depths of up to 19 feet when full. Large cottonwood debris piles occur throughout the floodplain, and the depression is dominated by vegetation with open areas in deeper portions. The Above-Brennan floodplain retains water to overwinter fish, but summer kills occur if water in the floodplain is not freshened in the second flood cycle (i.e., after 12 months). The Above-Brennan floodplain has been used as a principal site to evaluate growth and survival of hatchery razorback sucker and bonytail under various densities of nonnative fishes.

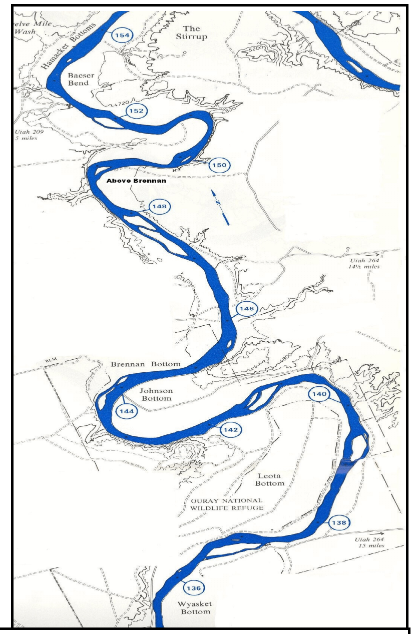


Figure 6-14. Map and aerial photo of the Above-Brennan floodplain.

__Role in Recovery__. The Above-Brennan floodplain is potentially an important nursery for razorback sucker. It is about 45 miles downstream of the known spawning bar for razorback sucker and can potentially entrain large numbers of drifting larvae because of the multiple breaches (Table B-2). Expansion of the razorback sucker population may result in additional spawning sites. Potential spawning bars exist about 15 miles upstream of this site, based on captures of wild and hatchery adult razorback sucker (Valdez and Masslich 1989; Tyus and Karp 1990).

__Objectives And Management Actions__

Objective 10-1. Evaluate floodplain effectiveness.

The Above-Brennan floodplain is deep and holds water year-around, but water quality may degrade after 12 months unless it is freshened by river inflow. Actions taken by the Recovery Program to maximize entrainment through upstream and downstream levee breaches should be evaluated for effectiveness of this floodplain site as a nursery for razorback sucker.

✔ **Management Action 10-1A. __Monitor/evaluate effectiveness of levee breaches to entrain and retain water at various river stages__.**

The levee that separates Above-Brennan floodplain from the main river channel was breached at the downstream end in 1997 and at the upstream end in 2000. No further breaches are recommended until evaluation is performed. The effectiveness of these breaches should be evaluated to determine if this strategy works for entraining larvae. Further modification may be necessary if the levee breaches are substantially modified by channel dynamics, or if entrainment can be significantly increased. Flow characteristics at the Above-Brennan floodplain should be assessed to determine the combination of river flows and levee management at which larval entrainment is maximized.

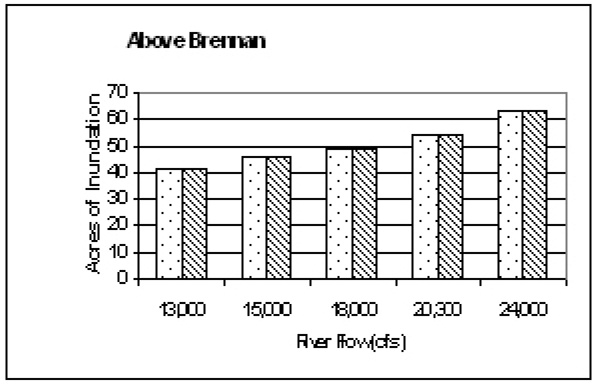


Figure 6-15. Relationship of Green River flow to acres of flooded bottomland at the Above-Brennan site with (light) and without (dark) levees.

✔ **Management Action 10-1B.** **<u>Periodically assess fish entrainment, growth, and survival</u>.**

The Above-Brennan floodplain is a small and readily accessible site that has been used to evaluate best strategies for maximizing growth and survival of razorback sucker and bonytail. Further assessment of growth and survival at this floodplain is not recommended until a synthesis of information is assimilated and interpreted in a Comprehensive Growth/Survival Report.

The Above-Brennan floodplain levee was breached at four locations and the effectiveness of these breaches to entrain water should be evaluated. The Above-Brennan floodplain should be allowed to function as a natural floodplain that inundates with spring runoff. This requires no active management, except monitoring of breaches and inundation to ensure that the floodplain depression is functioning properly. Levee and breach reconstruction may be necessary if the floodplain is not functioning as a 12 or 24–month reset floodplain.

6.2.11 Johnson Bottom (RM 264.5)

***<u>Background</u>*.** Johnson Bottom is located on the east bank of the Green River about 26 miles downstream of the State Highway 40 bridge to Bonanza, Utah, on lands administered by ONWR (Figure 6-16). Johnson Bottom is a large floodplain that is separated from the river channel by a natural and man-made levee that is topped at high river flows. The floodplain is divided into four ponds (J-1 through J-4) that are separated by three dikes constructed by the ONWR for waterfowl management (Figure 6-17). These internal dikes were breached by the ONWR in 1998, resulting in 146 flooded acres. Johnson Bottom holds water overwinter and can support fish for extended time periods. In 1998, the levee was breached connecting unit J-4 to the river, making the entire area floodable at about 13,000 cfs (Flo Engineering 1997). A second breach was excavated by the Recovery Program to connect unit J-3 to the river and a gate and kettle were installed to control water and fish. Nevertheless, the base elevation of the floodplain is below the river bed elevation and the site does not drain completely.

Role In Recovery. The need for further restoration of Johnson Bottom should be determined following restoration and evaluation of Thunder Ranch and Stewart Lake and response by the razorback sucker and bonytail populations to all floodplain management actions. If a need for additional restoration is identified, the Recovery Program should establish a partnership with the ONWR to develop restoration and management strategies compatible with program needs and refuge goals and objectives.

Johnson Bottom can be an important nursery for razorback sucker, given the large area of inundation. However, the site is about 47 miles downstream of the known spawning bar for razorback sucker, and the number of drifting larvae reaching this site may currently be small (Table B-2). Levee breaches currently allow Johnson Bottom to flood and entrain fish, but the base elevation of the floodplain is below the elevation of the river bed and the site does not consistently drain and reset.

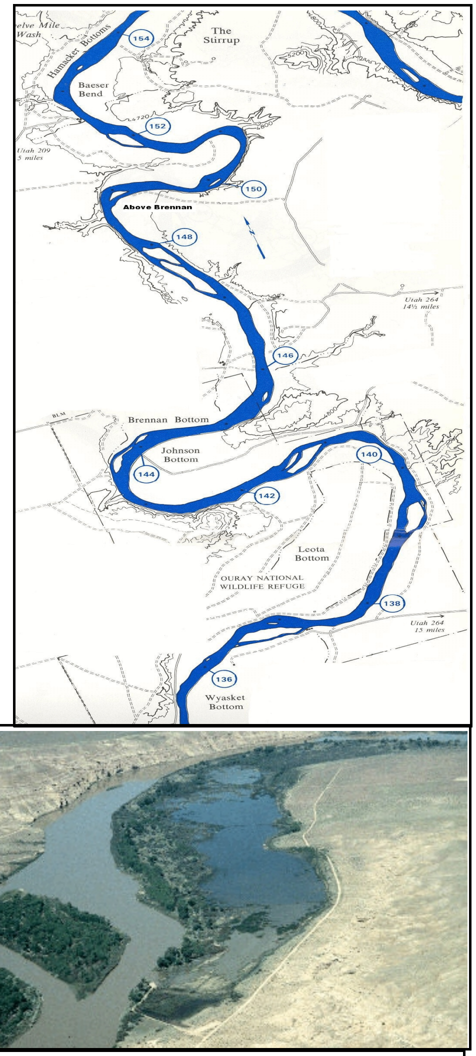


Figure 6-16. Map and aerial photo of Johnson Bottom.

Objectives And Management Actions

Objective 11-1. Coordinate with ONWR to manage Johnson Bottom to benefit razorback sucker and bonytail.

The Recovery Program should coordinate with ONWR to manage Johnson Bottom to maximize flood potential, entrainment of larval fish, and overwintering of fish. Management actions should not negatively impact the goals and objectives of ONWR. Further restoration may be necessary, pending the outcome of restoration and evaluation at Thunder Ranch and Stewart Lake and response by the razorback sucker and bonytail populations. Best restoration strategies should first be identified, based on evaluation of past and ongoing restoration, before additional work is done on Johnson Bottom.

✔ **Management Action 11-1A. Establish a partnership between the Recovery Program and ONWR to further restore Johnson Bottom.**

The Recovery Program should seek to establish a partnership with ONWR if further restoration of Johnson Bottom becomes necessary. The partnership should be based on agreements for restoration activities, management actions, and cost-sharing. Further restoration of Johnson Bottom may be necessary if restoration and management actions at other sites identified in this Plan are inadequate to establish and maintain a self-sustaining population of razorback sucker. Restoration of Johnson Bottom may also be necessary if the population of razorback sucker expands and additional spawning sites are established that produce sufficient numbers of larvae for entrainment in the Johnson Bottom area.

✔ **Management Action 11-1B. Develop a Summary Action Plan I.**

A Summary Action Plan I should be developed jointly by the Recovery Program and ONWR to provide an overview of management actions for Johnson Bottom and Leota Ponds (see section 6.2.12), if the Recovery Program decides that further action at Johnson Bottom is necessary. This action plan should be the basis of the partnership between the Recovery Program and ONWR and does not need to contain detailed management actions and engineering designs.

Objective 11-2. Evaluate floodplain effectiveness.

✔ **Management Action 11-2A. Implement and evaluate management actions.**

The Recovery Program should evaluate activities implemented under management action 11-1B to insure that the floodplain is an effective habitat for razorback sucker.

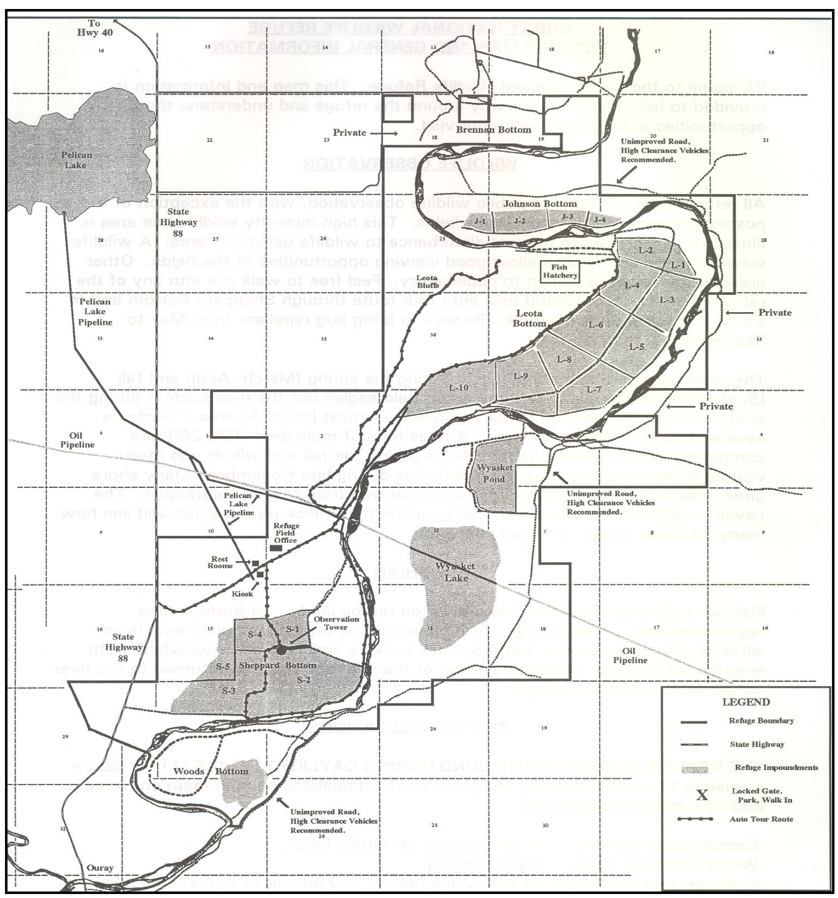


Figure 6-17. Map of Ouray National Wildlife Refuge and significant floodplain sites.

6.12 Leota Ponds (RM 257-262)

Background. Leota Ponds is located on the west bank of the Green River about 33 miles downstream of the State Highway 40 bridge to Bonanza, Utah, and about 10 miles upstream from the State Highway 88 bridge (Watson Road) near Ouray, Utah, on lands administered by ONWR (Figure 6-18). Leota Ponds is a large floodplain that is separated from the river channel by a natural and man-made levee that is topped at high river flows. The levee was breached at two locations by the Recovery Program in March 1998; one breach connects unit L-7 to the river and the second connecting unit L-7A includes a water control gate and fish kettle. These breaches allow the river to flood about 59 acres at river flows of 13,000 cfs (Figure 6-19; Flo Engineering 1997). The floodplain is divided into 10 ponds (L-1 through L-10) separated by internal dikes constructed by the ONWR to benefit waterfowl (Figure 6-17). These internal dikes were breached by the ONWR in 1998, resulting in 1,016 floodable acres at 13,000 cfs. There is currently a conduit to bring fresh water to the Leota floodplain from Pelican Lake. Leota Ponds cannot be completely drained, but water remaining over winter is shallow and may freeze with low fish survival. Leota Ponds has a high potential for management as a 12 or 24-month nursery for razorback sucker, but the ponds may need to be re-engineered to ensure complete draining during the "reset" period.

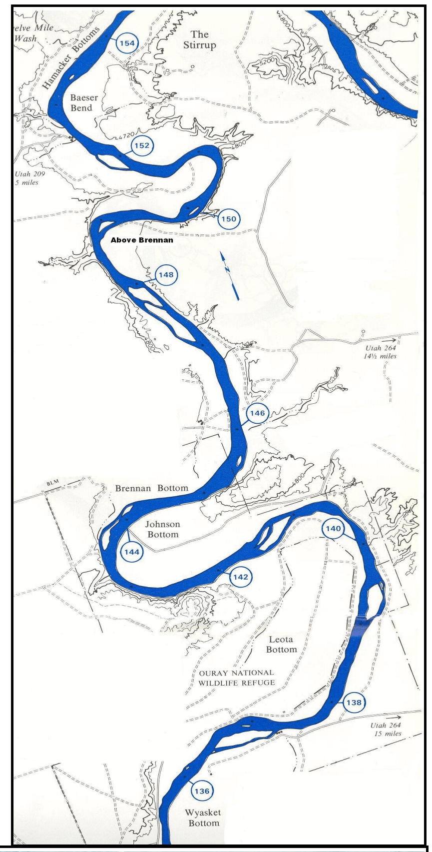


Figure 6-18. Map and aerial photo of Leota Ponds.

Role In Recovery. The need for further restoration of Leota Ponds should be determined following restoration and evaluation of Thunder Ranch and Stewart Lake and response by the razorback sucker and bonytail populations to all floodplain management actions. If a need for additional restoration is identified, the Recovery Program should establish a partnership with the ONWR to develop restoration and management strategies compatible with program and refuge goals and objectives.

Leota Ponds can be an important nursery for razorback sucker, given the large area of inundation. The site is about 52 miles downstream of the known spawning bar for razorback sucker, and the number of drifting larvae reaching this site may currently be small (Table B-2). Expansion of the razorback sucker population will likely result in greater numbers of drifting larvae and possibly additional spawning sites, which could result in greater numbers of larvae in the Leota Ponds area.

Objectives And Management Actions

Objective 12-1. Coordinate with ONWR to manage Leota Ponds to benefit razorback sucker.

The Recovery Program should coordinate with ONWR to manage Leota Ponds to maximize flood potential, entrainment of larval fish, and overwintering of fish. Management actions should not negatively impact the goals and objectives of ONWR. Further restoration may be necessary, pending the outcome of restoration and evaluation at Thunder Ranch and Stewart Lake and response by the razorback sucker and bonytail populations. Best restoration strategies should first be identified, based on evaluation of past and ongoing restoration, before additional work is done on Leota Ponds.

✔ **Management Action 12-1A. Establish a partnership between the Recovery Program and ONWR to further restore Leota Ponds.**

The Recovery Program should seek to establish a partnership with ONWR if further restoration of Leota Ponds becomes necessary. The partnership should be based on agreements for restoration activities, management actions, and cost-sharing. Further restoration of Leota Ponds may be necessary if restoration and management actions at other sites identified in this Plan are inadequate to establish and maintain a self-sustaining population of razorback sucker. Restoration of Leota Ponds may also be necessary if the population of razorback sucker expands and additional spawning sites are established that produce sufficient numbers of larvae for entrainment in the Leota Ponds area.

✔ **Management Action 12-1B. Develop a Summary Action Plan I.**

A Summary Action Plan I should be developed jointly by the Recovery Program and ONWR to provide an overview of management actions for Leota Ponds and Johnson Bottom (see section 6.2.11), if the Recovery Program decides that further action at Leota Ponds is necessary. This action plan should be the basis of the partnership between the Recovery Program and ONWR and does not need to contain detailed management actions and engineering designs.

Objective 12-2. Evaluate floodplain effectiveness.

✔ **Management Action 12-2A. Implement and evaluate management actions.**

The Recovery Program should evaluate activities implemented under management action 12-1B to insure that the floodplain is an effective habitat for razorback sucker.

6.1.13 Wyasket Lake (RM 253-257)

Background. Wyasket Lake (Wyasket Bottom) is located on the east bank of the Green River about 7 miles upstream from the State Highway 88 bridge (Watson Road) near Ouray, Utah, on lands administered by ONWR (Figure 6-19). Wyasket Lake is a large shallow depression that was originally classified as a terrace floodplain; however, it has a depression and a deep trench that holds water for short time periods. Water seeps into this floodplain before surface connection with the river, but most of the floodplain dries seasonally after runoff. Floodable area is about 304 acres at about 13,000 cfs and about 850 acres at 18,600 cfs (Figure 6-20; Flo Engineering 1997). Although some water and fish may hold in the depression and trench, the majority of the floodplain does not hold water during summer and over winter.

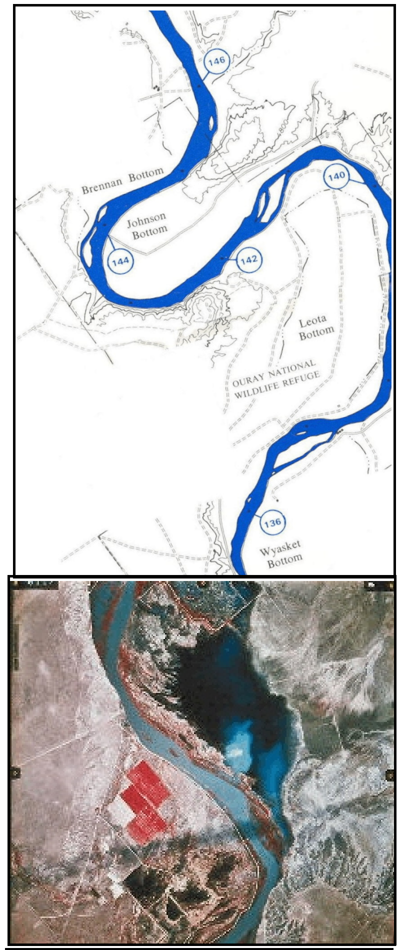


Figure 6-19. Map and aerial photo of Wyasket Lake (photo right center).

Role In Recovery. Wyasket Lake currently has limited value for recovery of razorback sucker. The site is shallow with little potential to hold water and support fish year-around. Wyasket Lake is about 55 miles downstream of the known spawning bar for razorback sucker, and the number of drifting larvae reaching this site may currently be small (Table B-2). No restoration has occurred at Wyasket Lake and none is recommended at this time. Adult razorback sucker, Colorado pikeminnow, and bonytail may use Wyasket Lake as transient habitat during spring runoff.

Objectives And Management Actions

Objective 13-1. Coordinate with ONWR to manage Wyasket Lake to benefit razorback sucker, if necessary.

The Recovery Program should coordinate with ONWR to manage Wyasket Lake to maximize flood potential, entrainment of larval fish, and overwintering of fish, if necessary. Further restoration may be necessary, pending the outcome of restoration efforts at Thunder Ranch, Stewart Lake, Leota Ponds, and Johnson Bottom, and response by the razorback sucker and bonytail populations. Best restoration strategies should first be identified, based on evaluation of past and ongoing restoration, before additional work is done on Wyasket Lake. Management actions should not negatively impact the goals and objectives of ONWR.

✔ **Management Action 13-1A. <u>Establish a partnership between the Recovery Program and ONWR to further restore Wyasket Lake, if necessary.</u>**

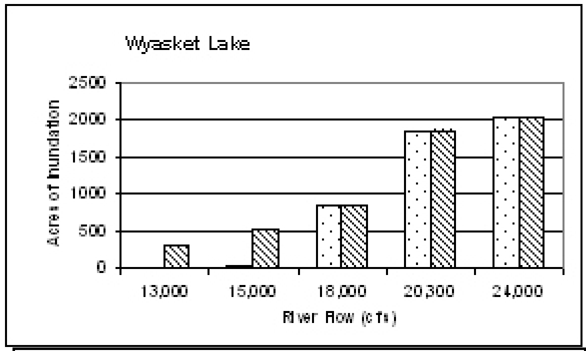


Figure 6-20. Relationship of Green River flow to acres of flooded bottomland at the Wyasket Lake site with (light) and without (dark) levees.

The Recovery Program should seek to establish a partnership with ONWR if further restoration of Wyasket Lake becomes necessary. The partnership should be based on agreements for restoration activities, management actions, and cost-sharing. Further restoration of Wyasket Lake may be necessary if restoration and management actions at other sites identified in this Plan are inadequate to establish and maintain a self-sustaining population of razorback sucker. Restoration of Wyasket Lake may also be necessary if the population of razorback sucker expands and additional spawning sites are established that produce sufficient numbers of larvae for entrainment in the Wyasket Lake area.

✔ **Management Action 13-1B. <u>Develop a Summary Action Plan II.</u>**

A Summary Action Plan II should be developed jointly, as necessary, by the Recovery Program and ONWR to provide an overview of management actions for Wyasket Lake, Sheppard Bottom, and Old Charlie Wash−Diked, if the Recovery Program decides that further action at Wyasket Lake is necessary. This action plan should be the basis for a partnership between the Recovery Program and ONWR and does not need to contain detailed management actions and engineering designs.

Objective 13-2. Evaluate floodplain effectiveness.

✔ **Management Action 13-2A. <u>Implement and evaluate management actions</u>.**

The Recovery Program should evaluate activities implemented under management action 13-1B to insure that the floodplain is an effective habitat for razorback sucker.

6.1.14 Sheppard Bottom (RM 254-256)

<u>Background</u>. Sheppard Bottom is located on the west bank of the Green River about 4.5 miles upstream from the State Highway 88 (Watson Road) near Ouray, Utah, on lands administered by ONWR (Figure 6-21). Sheppard Bottom is a large shallow depression that is separated from the river channel by a natural and man-made levee that is topped at high river flows of about 25,300 cfs. The floodplain is divided into five ponds (S-1 through S-5) separated by dikes constructed by the ONWR to benefit waterfowl (Figure 6-17). Water seeps into this floodplain before river surface connection occurs, but the floodplain lacks a reliable low-flow connection to the river. High selenium concentrations reported in the "north pond" and "south pond" of Sheppard Bottom were mitigated by filling the concentration sites with earth, although the ponds have not been recently evaluated for selenium concentration. Sheppard Bottom is a large floodplain with a potential floodable area of about 1,350 acres (Flo Engineering 1997). Although some water and fish may hold in the depression, the majority of the floodplain area is terraced and does not hold water.

<u>Role In Recovery</u>. Sheppard Bottom may be an important nursery for razorback sucker, given the large area of inundation. The site is about 58 miles downstream of the known spawning bar for razorback sucker, and the number of drifting larvae reaching this site may currently be small (Table B-2). Expansion of the razorback sucker population could result in greater numbers of drifting larvae and possibly additional spawning sites. Sheppard Bottom may provide transient habitat for adult Colorado pikeminnow, razorback sucker, and bonytail during high water levels.

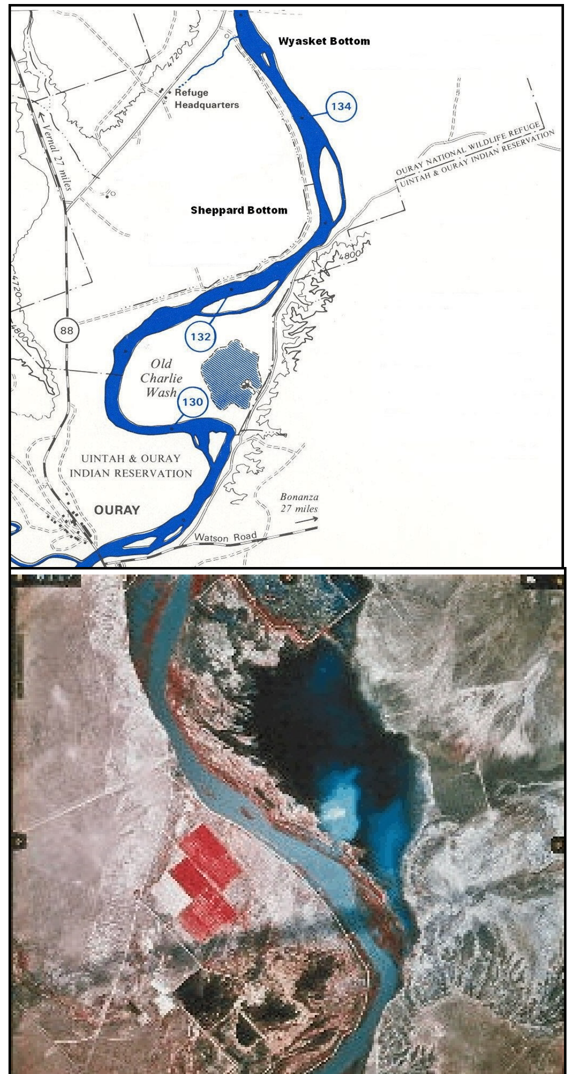


Figure 6-21. Map and aerial photo of Sheppard Bottom (photo lower center).

<u>Objectives And Management Actions</u>

Objective 14-1. Coordinate with ONWR to manage Sheppard Bottom to benefit razorback sucker.

The Recovery Program should coordinate with ONWR to manage Sheppard Bottom to maximize flood potential, entrainment of larval fish, and overwintering of fish, if necessary. Further restoration may be necessary, pending the outcome of restoration efforts at Thunder Ranch, Stewart Lake, Leota Ponds, and Johnson Bottom, and response by the razorback sucker and bonytail populations. Best restoration strategies should first be identified, based on evaluation of past and ongoing restoration, before additional work is done on Sheppard Bottom. Management actions should not negatively impact the goals and objectives of ONWR.

✔ **Management Action 14-1A. Establish a partnership between the Recovery Program and ONWR to further restore Sheppard Bottom, if necessary.**

The Recovery Program should seek to establish a partnership with ONWR if further restoration of Sheppard Bottom becomes necessary. The partnership should be based on agreements for restoration activities, management actions, and cost-sharing. Further restoration of Sheppard Bottom may be necessary if restoration and management actions at other sites identified in this Plan are inadequate to establish and maintain a self-sustaining population of razorback sucker. Restoration of Sheppard Bottom may also be necessary if the population of razorback sucker expands and additional spawning sites are established that produce sufficient numbers of larvae for entrainment in the Sheppard Bottom area.

✔ **Management Action 14-1B. Develop a Summary Action Plan II.**

A Summary Action Plan II should be developed jointly, as necessary, by the Recovery Program and ONWR to provide an overview of management actions for Wyasket Lake, Sheppard Bottom, and Old Charlie Wash−Diked, if the Recovery Program decides that further action at Sheppard Bottom is necessary. This action plan should be the basis for a partnership between the Recovery Program and ONWR and does not need to contain detailed management actions and engineering designs.

Objective 14-2. Evaluate floodplain effectiveness.

✔ **Management Action 14-2A. Implement and evaluate management actions.**

The Recovery Program should evaluate activities implemented under management action 14-1B to insure that the floodplain is an effective habitat for razorback sucker.

6.1.15 Old Charlie Wash (RM 249-252)

Background. Old Charlie Wash is a large floodplain located in Woods Bottom on the east bank of the Green River 2 miles upstream from the State Highway 88 bridge (Watson Road) near Ouray, Utah. Old Charlie Wash is owned by the Ute Indian Tribe and is managed for waterfowl by ONWR (Figure 6-22). Old Charlie Wash is divided into two units by an internal dike constructed by ONWR. The northeast (upstream) unit is called Old Charlie Wash–Main, and the southwest (downstream) unit is called Old Charlie Wash–Diked. Old Charlie Wash–Main receives inflow through a canal originating in a side channel of the Green River. A gate on the inlet channel regulates flow into Old Charlie Wash–Main. In 1997, the Recovery Program installed a downstream gate and fish kettle in Old Charlie Wash–Main to control and monitor fish movement to and from the Green River. The Recovery Program also breached the levee between the river and Old Charlie Wash–Diked. Old Charlie Wash–Diked has about 56 acres of flooded land at Green River flows of about 13,000 cfs and about 81 acres at 18,600 cfs.

Old Charlie Wash–Main has about 336 acres at flows of 14,000-16,000 cfs (Figure 6-23). Old Charlie Wash–Main fills and drains well. Old Charlie Wash–Diked is a shallow depression that does not hold water well, but may provide habitat for adult Colorado pikeminnow, bonytail, and razorback sucker during runoff. In 1999, northern pike spawned in Old Charlie Wash–Main.

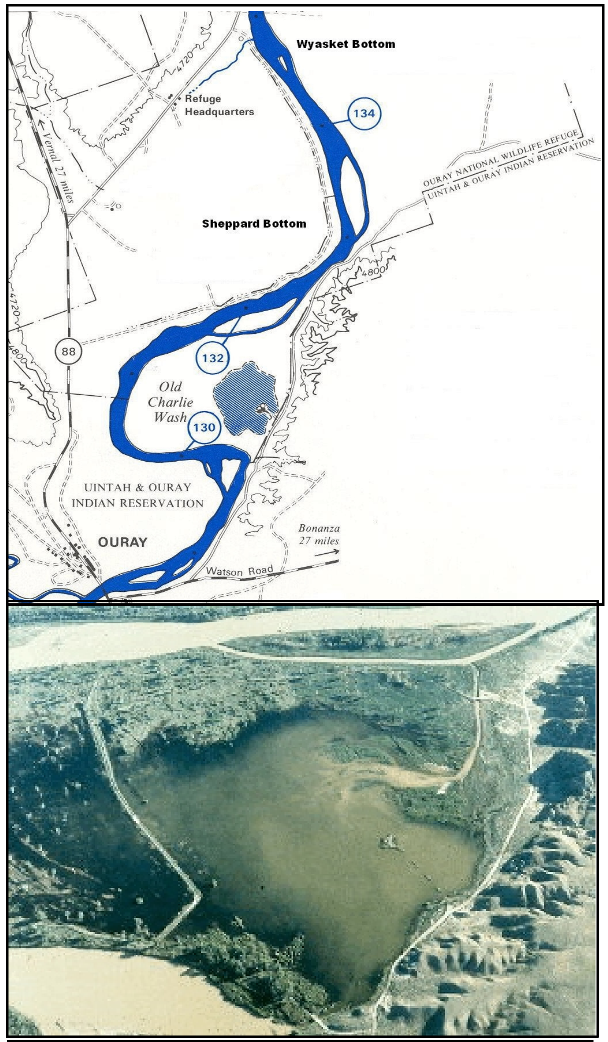


Figure 6-22. Map and aerial photo of Old Charlie Wash–Main (photo center) and Old Charlie Wash–Diked (photo left).

Growth of entrained razorback sucker in Old Charlie Wash – Main was evaluated and determined to be high, but survival was unknown. Young wild razorback sucker were found in Old Charlie Wash in 1995 and 1996, demonstrating that razorback sucker can survive in the presence of high densities of nonnative fishes (Modde 1997). A total of 28 juveniles (mean, 3.7 inches [94 mm] TL) were captured in October 1995, and 45 juveniles (mean, 2.6 inches [66 mm] TL) were captured in August 1996. Fish had no access to Old Charlie Wash after spring flows dropped to below 14,000 cfs on July 2, 1995, and on June 14, 1996; hence, the juveniles captured were presumed to have drifted into the floodplain as larvae during runoff in June of 1995 and 1996. The original numbers of razorback sucker are unknown, so survival cannot be assessed. Growth rate is considered high; according to the Floodplain Model, 4-month old fish are expected to be 58, 76, and 112 mm TL, respectively (compared to 94 mm TL), and 2-month old fish are expected to be 33, 37, and 59 mm TL, respectively (compared to 66 mm TL).

Role In Recovery. Old Charlie Wash has value as a recovery site for razorback sucker, based on previous capture and survival of wild fish. The site is about 60 miles downstream of the known spawning bar for razorback sucker, and the number of drifting larvae reaching this site may currently be small (Table B-2). Old Charlie Wash–Main currently functions as a 12 or possibly a 24-month depression floodplain. However, Old Charlie Wash–Diked is a shallow depression with poor water and larval retention that may have limited value for razorback sucker, except as transient adult habitat. Further modifications to Old Charlie Wash are not recommended at this time.

Objectives And Management Actions

Objective 15-1. Evaluate floodplain effectiveness.

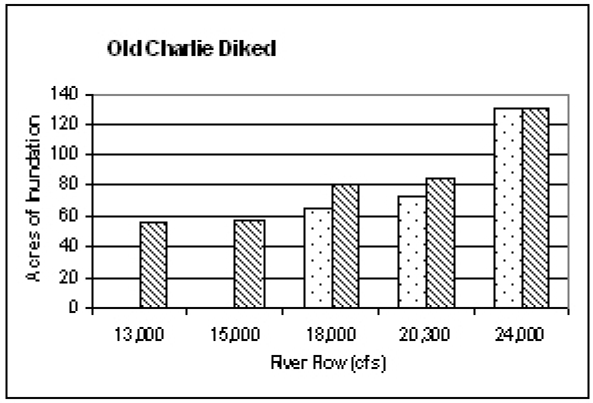


Figure 6-23. Relationship of Green River flow to acres of flooded bottomland at the Old Charlie Wash–Diked with (light) and without (dark) levees.

Old Charlie Wash is a moderately sized floodplain that could function to recover razorback sucker if water will remain a sufficient time period for growth, survival and escapement of fish. The Recovery Program breached the levee that separated Old Charlie Wash–Diked from the Green River in 1997, and installed a gate and fish kettle in Old Charlie Wash–Main to control and monitor fish movement to and from the river. Actions taken by the Recovery Program to maximize entrainment through upstream and downstream levee breaches should be evaluated for effectiveness of this floodplain site as a nursery for razorback sucker. No further breaches, modifications, or structures are recommended.

✔ **Management Action 15-1A. <u>Monitor/evaluate effectiveness of levee breaches to entrain and retain water at various river stages</u>.**

Old Charlie Wash–Diked becomes inundated at a river flow of 13,000-16,000 cfs. This floodplain does not hold water year-around in dry and average years, and often dries in the first summer following inundation. Entrained larvae would either have to leave the site with receding flows or become stranded and risk desiccation. This site will not function as a 12 or 24-month nursery in most years without substantial excavation, reconstruction, water pumps, and possibly aeration. No further Recovery Program activity is recommended for this site at this time and no specific management actions are recommended.

✔ **Management Action 15-1B. <u>Periodically assess fish entrainment, growth, and survival</u>.**

Old Charlie Wash should be allowed to inundate naturally. The water control gate on Old Charlie Wash–Main should be managed to retain water in the floodplain for up to 24 months followed by draining and desiccation to reset and kill the stranded nonnative fishes. No further studies of growth and survival of fish in Old Charlie Wash are recommended.

6.1.16 Lamb Property (RM 239-241)

Background. The Lamb Property floodplain is located on the west bank of the Green River beginning about 1 mile downstream from the State Highway 88 bridge (Watson Road) near Ouray, Utah. This floodplain is on private property, and the Recovery Program has acquired a perpetual easement for flooding of about 463 acres in three parcels. The Lamb Property floodplain complex extends from the Duchesne River confluence downstream about 5 miles through the West Branch (Figure 6-24). Most of the Lamb Property is terraced floodplains that flood and drain with the level of the river.

Role In Recovery. The Lamb Property floodplain is about 70 miles downstream of the known spawning bar for razorback sucker. Entrainment of significant numbers of drifting larvae in this floodplain is unlikely because of the distance from the spawning bar and retention of larvae is short because of the terrace nature of the floodplain.

Objectives And Management Actions

Objective 16-1. Protect the Lamb Property floodplain from man-made changes.

No specific management actions are recommended for the Lamb Property floodplain, except protection from man-made changes, including filling, reshaping, draining, or other activities not consistent with the easement agreement with the Recovery Program. This site currently functions as a terrace floodplain and inundation and larval retention is short-term and entirely related to river stage. Further investment of funds by the Recovery Program is not advised. The site may be re-evaluated at a later date if recovery criteria are not being achieved with ongoing actions.

Management Action 16-1A. Coordinate with landowner to ensure protection of the Lamb property.

The current easement agreement with the landowner precludes modifications to the site without conference and approval from the Recovery Program. This ensures protection of the site from modifications that could reduce the value of the overall Green River riparian ecosystem.

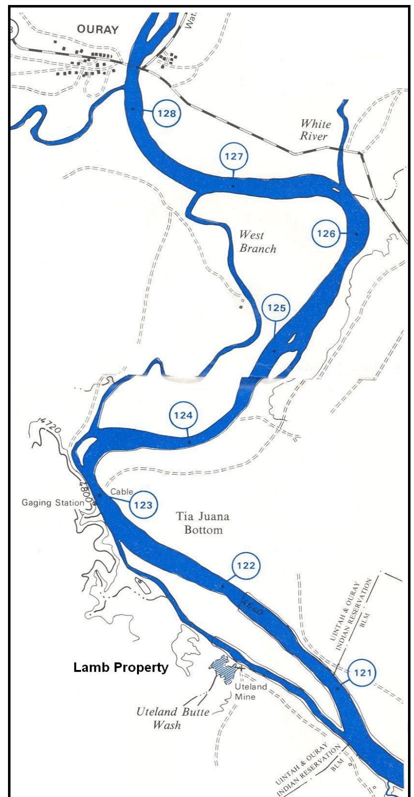


Figure 6-24. Map and aerial photo of the Lamb Property and West Branch.

Table 6-2. Summary of site features, objectives, and management actions for each of the 16 priority floodplains of the Split Mountain to Desolation Canyon reach.

Floodplain	Site Features	Objectives	Management Actions
1. Thunder Ranch	– Levee tops at 30,000 cfs – Levee will be breached in 2004 – Selenium remediation required – 5 miles from spawning bar – high potential nursery for razorback sucker	1-1. Restore inundation of floodplain 1-2. Reduce detrimental effects of selenium 1-3. Evaluate floodplain effectiveness	1-1A. Modify levee 1-2A. Implement selenium remediation 1-3A. Evaluate larval drift and entrainment 1-3B. Evaluate growth/survival of razorback sucker 1-3C. Assess effectiveness of management actions
2. IMC	– Large backwater functions as a terrace floodplain	2-1. Protect the IMC backwater from man-made changes – No further action recommended	2-1A. Coordinate with landowner to ensure protection
3. Stewart Lake	– Inlet/outlet control gates installed – Basin trenched to drain well – Water held 3–4 mo. to flush selenium – Floods at 7,500 cfs	3-1. Coordinate management of Stewart Lake 3-2. Evaluate floodplain effectiveness – Coordinate management with UDWR, Reclamation, and the Service required	3-1A. Coordinate with UDWR, BOR, USFWS 3-1B. Evaluate selenium remediation 3-2A. Evaluate larval drift and entrainment 3-2B. Evaluate growth/survival of razorback sucker 3-2C. Assess effectiveness of management actions
4. Sportman's Lake	– Single gated inlet/outlet – Floods at very high flows – Surrounding area floods	4-1. Coordinate possible future management – No action recommended except coordination for possible future use	4-1A. Coordinate with property owners and Uintah Sportman's Club, if necessary
5. Bonanza Bridge	– Holds water in wet years – Four breaches flood at 13,000 cfs – Small area (28 acres)	5-1. Evaluate floodplain effectiveness	5-1A. Monitor/evaluate effectiveness of levee breaches to entrain and retain water at various river stages 5-1B. Periodically assess fish entrainment, growth, survival
6. Richens/ Slaugh	– Fills/drains 78 acres as terrace – Enhancement will requires dikes to protect adjacent property	6-1. Protect the Richens/Slaugh floodplain from man-made changes – No action recommended	6-1A. Coordinate with landowners to ensure protection
7.Horseshoe Bend	– 1,000 foot breach floods 22 acres – Usually desiccates in summer – May hold water year-around in wet years	7-1. Restructure floodplain, if necessary 7-2. Evaluate floodplain effectiveness	7-1A. Modify levee, excavate basin, if necessary 7-2A. Implement/evaluate management actions, as necessary

Table 6-2. Continued

Floodplain	Site Features	Objectives	Management Actions
8. The Stirrup	– Single breach floods 28 acres – Holds water year-around	8-1. Evaluate floodplain effectiveness	8-1A. Monitor/evaluate effectiveness of levee breach to entrain and retain water at various river stages 8-1B. Periodically assess fish entrainment, growth, survival
9. Baeser Bend	– Single breach floods 47 acres – Holds water year-around	9-1. Evaluate floodplain effectiveness	9-1A. Monitor/evaluate effectiveness of levee breach to entrain and retain water at various river stages 9-1B. Periodically assess fish entrainment, growth, survival
10. Above Brennan	– Four breaches flood 50 acres – Holds water year-around – Water quality may degrade in summer	10-1. Evaluate floodplain effectiveness	10-1A. Monitor/evaluate effectiveness of levee breaches to entrain and retain water at various river stages 10-1B. Periodically assess fish entrainment, growth, survival
11. Johnson Bottom	– Levee breached with gate/kettle – Floods 146 acres – Does not drain completely – Partnership with ONWR needed	11-1. Coordinate with ONWR 11-2. Evaluate floodplain effectiveness	11-1A. Establish partnership with ONWR 11-1B. Develop Summary Action Plan I with ONWR 11-2A. Implement/evaluate management actions
12. Leota Ponds	– Levee breached with gate/kettle – Floods 1,016 acres – Does not drain completely – Partnership with ONWR needed	12-1. Coordinate with ONWR 12-2. Evaluate floodplain effectiveness	12-1A. Establish partnership with ONWR 12-1B. Develop Summary Action Plan I with ONWR 12-2A. Implement/evaluate management actions
13. Wyasket Lake	– Large shallow depression – Does not hold water long – Would require basin excavation – Partnership with ONWR needed	13-1.Coordinate with ONWR 13-2. Evaluate floodplain effectiveness	13-1A. Establish partnership with ONWR, if necessary 13-1B. Develop Summary Action Plan II with ONWR, if neces. 13-2A. Implement/evaluate management actions, as necessary
14. Sheppard Bottom	– No levee breaches – Floods at 25,300 cfs; 300 acres – Large shallow depression – Possible high selenium	14-1. Coordinate with ONWR 14-2. Evaluate floodplain effectiveness	14-1A. Establish partnership with ONWR, if necessary 14-1B. Develop Summary Action Plan II with ONWR, if neces. 14-2A. Implement/evaluate management actions, as necessary
15a. Old Charlie Wash–Main	– Inflow canal gated – Outlet gated with kettle – Fills/drains well	15-1a. Evaluate floodplain effectiveness	15a-1A. Monitor/evaluate effectiveness of levee breaches to entrain and retain water at various river stages 15a-1B. Periodically assess fish entrainment, growth, survival

Table 6-2. Continued

Floodplain	Site Features	Objectives	Management Actions
15. Old Charlie Wash–Diked	– Shallow, dries annually – Levee breached at 13,000 cfs – Floods about 81 acres	15-1b. Restructure floodplain, if necessary 15-2b. Evaluate floodplain effectiveness	15b-1A. Modify levee, excavate basin, if necessary 15b-1B. Develop Summary Action Plan II with ONWR, if nec. 15b-1C. Implement/evaluate management actions, as necessary
16. Lamb Property	– Large terrace – Fills/drains with river stage	16-1. Protect the Lamb Property floodplain from man-made changes – No action recommended	16-1A. Coordinate with landowners to ensure protection

7.0 PLAN IMPLEMENTATION

7.1 Suitability Of Floodplain Habitat

The Recovery Program currently has access to manage approximately 4,448 acres of potential floodplain habitat (at 18,600 cfs) at 16 sites within the Split Mountain to Desolation Canyon reach of the Green River Subbasin (Table 7-1). Model simulations estimate that this floodplain acreage exceeds the nursery habitat area necessary to establish and maintain a self-sustaining population of razorback sucker with 5,800 adults (Valdez 2004). However, restoration of key floodplains is necessary to convert shallow depressions and terraces into suitable, long-term depressions that will function according to the “reset theory” of floodplain management (see section 3.7).

Under existing conditions and Green River flows of 18,600 cfs at Jensen, Utah, the Split Mountain to Desolation Canyon reach has about 489 acres (5 sites) of long-term floodplain depressions and 3,959 acres (12 sites; Old Charlie Wash is treated as two sites) of shallow depressions and terraces, sites that only flood at very high river flows, or sites that do not drain well. Four of the five sites that total 489 acres (Bonanza Bridge, The Stirrup, Baeser Bend, Above-Brennan) were breached by the Recovery Program to flood at about 13,000 cfs and hold water year-around in average to wet years; the fifth site is Old Charlie Wash–Main.

This Plan identifies restoration of two additional floodplain sites as the first and second priority for floodplain management in the Green River Subbasin. These sites include Thunder Ranch (330 acres) and Stewart Lake (570 acres). Restoration of these sites should result in a total of 1,389 acres (i.e., 489 + 900) of suitable floodplain depressions. These sites are identified as priority sites because of their proximity to the razorback sucker spawning bar (Thunder Ranch, 5 miles; Stewart Lake, 11 miles), existing water control at Stewart Lake, large floodable area, and high management potential. The Recovery Program has a perpetual easement at Thunder Ranch, and has initiated coordination with UDWR, Reclamation, and the Service to develop a management strategy for Stewart Lake that does not negatively impact the purpose of the waterfowl management area and ongoing selenium remediation.

Priority floodplains and associated acreage of suitable floodplain depressions

1.	Thunder Ranch	330
2.	Stewart Lake	570
3.	Leota Ponds	1,016
4.	Johnson Bottom	146
	Existing (5 sites)	489
	Total:	2,551

Two floodplain sites in the ONWR are identified as the third and fourth priority restoration sites; Leota Ponds (1,016 acres) and Johnson Bottom (146 acres). Restoration of

Table 7-1. Prioritization of restoration for floodplain sites and associated acreage in the Split Mountain to Desolation Canyon reach at 18,600 cfs flows of the Green River at Jensen, Utah. Old Charlie Wash is treated as two sites (Main and Diked).

Priority	Site	Floodplain Area (acres)	Existing Suitable Floodplain Depressions	Restore To Suitable Floodplain Depressions			
				Phase I	Phase II	Phase III	Total
1	Thunder Ranch	330		330			330
2	Stewart Lake	570		570			570
3	Leota Ponds	1,016			1,016		1,016
4	Johnson Bottom	146			146		146
5	Sheppard Bottom	300				300	300
6	Wyasket Lake	850				850	850
7	Sportsman's Lake	132				132	132
8	Horseshoe Bend	22				22	22
9	Old Charlie–Diked	81				81	81
10	Bonanza Bridge	28	28				
11	The Stirrup	28	28				
12	Baeser Bend	47	47				
13	Above Brennan	50	50				
14	Old Charlie–Main	336	336				
15	Lamb Property	463					
16	Richens, Slaugh	45					
17	IMC	4					
Total Acreage And By Phase:		4,448		900	1,162	1,385	3,447
Cumulative Total Suitable Floodplain Acreage:			489	1,389	2,551	3,936	

these sites is important to accommodate fish population expansion and additional spawning sites, and because of the large potential floodable area and existing water control structures. Some restoration has taken place at these sites, including levee breaches and installation of water control gates and fish kettles by the Recovery Program, and removal or breaches of internal dikes by ONWR. The need for additional restoration of these sites will be determined following restoration and evaluation of Thunder Ranch and Stewart Lake and response by razorback sucker and bonytail to these management actions. If the need for additional restoration is identified, the Recovery Program should establish a partnership with the ONWR to develop restoration and management strategies compatible with Recovery Program needs and refuge goals and objectives. Restoration of the two sites on the ONWR would result in an additional 1,162 acres of suitable floodplain depressions for a total of 2,551 acres (i.e., 1,389 + 1,162) at 9 sites located 5–60 miles downstream from the known spawning bar.

Restoration of Sheppard Bottom (300 acres), Wyasket Lake (850), Sportsman's Lake (132), Horseshoe Bend (22), and Old Charlie–Diked (81) would be fully or partially implemented, as necessary, based on lack of success with other floodplain restoration activities, or if population expansion of razorback sucker or bonytail merits additional floodplain sites. Restoration of Sheppard Bottom, Wyasket Lake, Horseshoe Bend, and Old Charlie–Diked may require mechanical excavation of the floodplain basins to insure long-term retention of water and proper draining. These actions could be costly and may not be necessary if other floodplain sites are suitable for species recovery. Sportsman's Lake is under private ownership and may require purchase of a property easement as well as structural modification to the inlet and levees, and possible excavation of an outlet. Restoration of these five sites could increase suitable floodplain depression habitat by 1,385 acres for a total of 3,936 acres (2,551 + 1,385).

Three sites (Lamb Property, Richens/Slaugh, and IMC) are not identified for restoration in this Plan because of high possible costs of reconstruction. The Lamb Property encompasses a large area and portions could be segmented into floodplain depressions. Richens/Slaugh floodplain would have to be diked to prevent flooding of adjacent properties, and IMC backwater is a small area that would require excavation. These sites may function as nursery habitat and transient adult habitat in high prolonged spring flows, despite the lack of restoration activities.

Model simulations show that the average amount of floodplain habitat necessary to support a self-sustaining population of 5,800 adult razorback sucker is 2,032 acres. This average is based on the amount of floodplain habitat computed for each of nine combinations of low, moderate, and high fish density and growth rate; model output ranged from 206 to 8,131 acres (Table 7-2; Valdez 2004). Model simulations show that existing floodplain habitat (i.e., 489 acres) satisfies only 3 of the 9 fish density/growth rate scenarios, and is probably not sufficient floodplain depression habitat for recovery. Phase I restoration will increase suitable floodplains to 1,389 acres, which satisfies 5 of the 9 fish density/growth rate scenarios, but is less than the overall average need of 2,032 acres. Fish response to floodplain restoration and management will need to be monitored and evaluated to determine if Phase II restoration is necessary, which could result in a total of 2,551 acres of suitable floodplain habitat. This would satisfy 7 of the 9 fish density/growth rate scenarios, and exceeds the overall average need of 2,032 acres.

A minimum area of floodplain habitat that meets Floodplain Model simulations may not be adequate for species recovery because quality, suitability, degree of connection, and larval entrainment vary by floodplain for a given river stage. Estimated acreage of suitable floodplains should exceed model predictions to buffer floodplain variability and to insure survival and recruitment in as many years as possible, considering the pulsed recruitment by razorback sucker.

Table 7-2. Floodplain area (acres) needed to meet 30% average annual recruitment for a razorback sucker population of 5,800 adults, based on three levels each of fish density and growth rate. Areas were derived from the Floodplain Model (Valdez 2004).

Growth Rate	Fish Density		
	Low	Moderate	High
Low	1,555	364	206
Moderate	3,698	864	489
High	8,131	1,901	1,076

7.2 Implementation

This Plan will be implemented in three phases that represent restoration priorities for specific floodplain sites (Figure 7-1). The three phases may be partially or entirely implemented and span from calendar year 2004 to 2015. This is an approximate time line because of the uncertainty regarding effectiveness of management actions (e.g., levee breaches, selenium remediation), annual variation of river stage (i.e., low spring runoff precludes effective evaluation of breaches and water entrainment), and availability of construction, research, and evaluation funds. The time line for the three phases corresponds to 12 of the 14 years estimated to establish self-sustaining populations of razorback sucker and bonytail in the Green River and Upper Colorado River subbasins (U.S. Fish and Wildlife Service 2002a, 2002b). A summary of management actions (see section 6.2) for each floodplain site is provided in Table 7-3.

7.2.1 Phase I

Phase I (i.e., restoration of Thunder Ranch and Stewart Lake) should be implemented in 2004. Topographic surveys have been completed for Thunder Ranch and levee breaches are scheduled for 2004. Accordingly, entrainment studies should be performed to evaluate the effectiveness of the breaches. Survival and growth should also be evaluated for razorback sucker and bonytail in the Thunder Ranch floodplain, and invasion by nonnative fishes should be assessed. Selenium remediation is also planned to start in 2004, and effectiveness of that action should also be evaluated.

Floodplain Management Plan Phases:				PHASE I				PHASE II				PHASE III											
Calendar Years:		'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23
Approximate Species Recovery Time Line:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Primary Species Recovery Elements:		Establish Self-Sustaining Populations of Razorback Sucker/Bonytail->														Downlist/Delist Monitoring---------->							
Priority	Floodplain Site			Approximate Time Period For Management Actions Summarized In Table 7-3																			
1	Thunder Ranch			<--------------->																			
2	Stewart Lake			<--------------->																			
3	Leota Ponds							<------------------->															
4	Johnson Bottom							<------------------->															
5	Sheppard Bottom											<------------------->											
6	Wyasket Lake											<------------------->											
7	Sportsman's Lake											<~~~~~~~~~~~~~~>											
8	Horseshoe Bend											<~~~~~~~~~~~~~~>											
9	Old Charlie–Diked											<~~~~~~~~~~~~~~>											
10	Bonanza Bridge				^	^	^	^	^	^	^	^	^	^	^								
11	The Stirrup				^	^	^	^	^	^	^	^	^	^	^								
12	Baeser Bend				^	^	^	^	^	^	^	^	^	^	^								
13	Above Brennan				^	^	^	^	^	^	^	^	^	^	^								
14	Old Charlie–Main				^	^	^	^	^	^	^	^	^	^	^								

Figure 7-1. Estimated time line for the three phases of the floodplain management plan compared to the recovery time line in years for razorback sucker and bonytail. See Table 7-3 for summary of management actions. Old Charlie Wash is treated as two sites (Main and Diked). Symbols (^) for priority sites 10–14 indicate ongoing monitoring and evaluation.

Table 7-3. Summary of management actions and success criteria for each prioritized floodplain site in the Split Mountain to Desolation Canyon Reach. Sites are ordered by priority and are numbered with management actions in the order described in section 6.2. Old Charlie Wash is treated as two sites (Main and Diked).

Priority	Floodplain	Management Actions	Success Criteria
Phase I 1	1. Thunder Ranch	1-1A. Modify levee 1-2A. Implement selenium remediation 1-3A. Evaluate larval drift and entrainment 1-3B. Evaluate growth/survival of razorback sucker 1-3C. Assess effectiveness of management actions	1-1A. Excavate levee breaches 1-2A. Selenium concentration effectively reduced 1-3A. Comprehensive Larval Drift Report 1-3B. Comprehensive Growth/Survival Report 1-3C. Assessment completed
2	3. Stewart Lake	3-1A. Coordinate management of Stewart Lake 3-1B. Evaluate selenium remediation 3-2A. Evaluate larval entrainment 3-2B. Evaluate growth/survival of razorback sucker 3-2C. Assess effectiveness of management actions	3-1A. Coordination with UDWR, BOR, USFWS 3-1B. Selenium concentration effectively reduced 3-2A. Comprehensive Larval Drift Report 3-2B. Comprehensive Growth/Survival Report 3-2C. Assessment completed
Phase II 3	12. Leota Ponds	12-1A. Establish partnership with ONWR 12-1B. Develop Summary Action Plan I with ONWR 12-2A. Implement/evaluate management actions	12-1A. Partnership established 12-1B. Summary Action Plan I executed 12-2A. Actions implemented/evaluated
4	11. Johnson Bottom	11-1A. Establish partnership with ONWR 11-1B. Develop Summary Action Plan I with ONWR 11-2A. Implement/evaluate management actions	11-1A. Partnership established 11-1B. Summary Action Plan I executed 11-2A. Actions implemented/evaluated
Phase III 5	14. Sheppard Bottom	14-1A. Establish partnership with ONWR, if necessary 14-1B. Develop Summary Action Plan II with ONWR, if neces. 14-2A. Implement/evaluate management actions, as necessary	14-1A. Partnership established, as necessary 14-1B. Summary Action Plan II executed, as neces. 14-2A. Actions implemented/evaluated, as necessary
6	13. Wyasket Lake	13-1A. Establish partnership with ONWR, if necessary 13-1B. Develop Summary Action Plan II with ONWR, if neces. 13-2A. Implement/evaluate management actions, as necessary	13-1A. Partnership established, as necessary 13-1B. Summary Action Plan II executed, as neces. 13-2A. Actions implemented/evaluated, as necessary
7	4. Sportsman's Lake	4-1A. Coordinate with property owners and Uintah Sportsman's Club, if necessary	4-1A. Coordination established with property owners and Uintah Sportsman's Club, as necessary
8	7. Horseshoe Bend	7-1A. Modify levee, excavate basin, if necessary 7-1B. Implement/evaluate management actions, as necessary	7-1A. Levee modified, basin excavated, as necessary 7-1B. Actions implemented/evaluated, as necessary

Table 7-3. Continued

Priority	Floodplain	Management Actions	Success Criteria
9	15b. Old Charlie Wash–Diked	15b-1A. Modify levee, excavate basin, if necessary 15b-1B. Develop Summary Action Plan II with ONWR, if nec. 15b-1C. Implement/evaluate management actions, as necessary	15b-1A. Levee modified, basin excavated, as neces. 15b-1B. Summary Action Plan II executed, as neces. 15b-1C. Actions implemented/evaluated, as neces.
Existing 10	5. Bonanza Bridge	5-1A. Monitor/evaluate effectiveness of levee breaches to entrain and retain water at various river stages 5-1B. Periodically assess fish entrainment, growth, survival	5-1A. Floodplain effectively entrainsand retainswater at flows ≥ 18,600 cfs 5-1B. Fish entrainment, growth, survival assessed
11	8. The Stirrup	8-1A. Monitor/evaluate effectiveness of levee breach to entrain and retain water at various river stages 8-1B. Periodically assess fish entrainment, growth, survival	8-1A. Floodplain is effectively entraining and retaining water at flows ≥ 18,600 cfs 8-1B. Fish entrainment, growth, survival assessed
12	9. Baeser Bend	9-1A. Monitor/evaluate effectiveness of levee breach to entrain and retain water at various river stages 9-1B. Periodically assess fish entrainment, growth, survival	9-1A. Floodplain is effectively entraining and retaining water at flows ≥ 18,600 cfs 9-1B. Fish entrainment, growth, survival assessed
13	10. Above Brennan	10-1A. Monitor/evaluate effectiveness of levee breaches to entrain and retain water at various river stages 10-1B. Periodically assess fish entrainment, growth, survival	10-1A. Floodplain is effectively entraining and retaining water at flows ≥ 18,600 cfs 10-1B. Fish entrainment, growth, survival assessed
14	15a. Old Charlie Wash–Main	15a-1A. Monitor/evaluate effectiveness of site to entrain and retain water at various river stages 15a-1B. Periodically assess fish entrainment, growth, survival	15a-1A. Floodplain is effectively entraining and retaining water at flows ≥ 18,600 cfs 15a-1B. Fish entrainment, growth, survival assessed
No Action 15	16. Lamb Property	16-1A. Coordinate with landowners to ensure protection	16-1A. No significant changes to floodplain
16	6. Richens/ Slaugh	6-1A. Coordinate with landowners to ensure protection	6-1A. No significant changes to floodplain
17	2. IMC	2-1A. Coordinate with landowner to ensure protection	2-1A. No significant changes to floodplain

Coordination has been initiated by the Recovery Program with UDWR, Reclamation, and the Service on Stewart Lake. High concentrations of selenium are reported in Stewart Lake, and a tile collector system will be installed in 2004 to capture and divert selenium from the lake. If the procedure effectively reduces selenium, it may become possible to retain water in Stewart Lake long enough to achieve sufficient size of razorback sucker. Larval entrainment should be evaluated for Stewart Lake, as well as growth and survival. The management strategy must balance endangered species needs with the stated purpose of the Stewart Lake Waterfowl Management Area and necessary selenium remediation.

7.2.2 Phase II

Phase II of this Plan (i.e., restoration of Leota Ponds and Johnson Bottom) will be implemented following restoration and evaluation of Thunder Ranch and Stewart Lake and response by razorback sucker and bonytail to these management actions. Restoration of these sites will be done in collaboration and under agreement with ONWR in a manner consistent with Recovery Program goals and ONWR goals and objectives. The time line for this phase is approximate because implementation will depend on the outcome of other floodplain management actions, as well as available Recovery Program funding.

7.2.3 Phase III

Phase III involves restoration of Sheppard Bottom, Wyasket Lake, Sportsman's Lake, Horseshoe Bend, and Old Charlie–Diked. Restoration of these floodplain sites may require substantial mechanical excavation of floodplain basins for costs that have not been determined, but may be substantial. Sportsman's Lake is under private ownership and may require purchase of a property easement as well as structural modification to the inlet and levees, and possible excavation of an outlet. These actions could be expensive and may not be necessary if other floodplain sites are suitable for species recovery. The time line provided for this phase is approximate because implementation will depend on the outcome of other floodplain management actions, as well as available Recovery Program funding.

7.3 Monitoring

A formal fish population monitoring program is not currently recommended to evaluate response to floodplain management actions. Numbers of razorback sucker and bonytail in the upper basin are currently too low to effectively monitor for population response. Increased numbers and distribution of razorback sucker and bonytail should be detectable through other ongoing Recovery Program activities, such as Colorado pikeminnow and humpback chub population estimates, nonnative fish control programs, and larval drift studies. All information on captured razorback sucker and bonytail should be incorporated into the Recovery Program database. The Service may decide to implement population monitoring consistent with species recovery goals. Effectiveness of levee breaches, floodplain inundation, larval entrainment, fish growth and survival, and selenium remediation should be evaluated, as appropriate for this Plan.

7.4 Success Criteria

Success criteria were developed in this Plan as a measure of achievement of management actions and potential contribution of each floodplain site to population size for recovery of razorback sucker and bonytail.

7.4.1 Achievement Of Management Actions

Success criteria for each floodplain site will be the achievement of management actions identified in section 6.2 of this Plan. A summary of management actions and success criteria is presented in Table 7-3. Accomplishment of the following items signifies successful achievement of management actions. The Recovery Program should monitor the achievement of these actions to track the progress and success of this Plan.

1. Successful restoration of Thunder Ranch floodplain.

Restoration of the Thunder Ranch floodplain will involve strategic breaches in the levee separating the floodplain from the main channel. These levee breaches should maximize flooding, larval entrainment, and retention of quality water for overwintering fish. Topographic surveys and levee designs are completed and excavation will begin in 2004. Evaluations should report successful entrainment of razorback sucker larvae, growth, and survival. An assessment of the floodplain should be performed to determine the success of management actions, and to identify additional activities, as necessary. It may be necessary, for example, to investigate the need for water control gates at Thunder Ranch to provide for better flooding and fish entrainment, as well as to hold suitable water quantity and quality to support fish for 12 or 24 months. Control gates would also allow for timed escape of fish from the floodplain to the main channel. The success of restoration of Thunder Ranch will be gaged by natural entrainment and production of razorback sucker to the Green River population (see section 7.4.2).

2. Effective reduction in selenium concentrations.

Selenium remediation is identified for two floodplain sites, Thunder Ranch and Stewart Lake. The source of selenium at Thunder Ranch has been identified as springs and seeps from agricultural runoff. Actions will be implemented in 2004 to collect some of this water and shunt it to the Green River for dilution and to prevent selenium-laden inflow to the floodplain. Selenium remediation at Stewart Lake is ongoing by the Service and Reclamation. A tile collector system will be installed and evaluated in 2004 to reduce selenium inflow and the need to frequently drain the lake. Selenium remediation may also be necessary at Sheppard Bottom, depending on the success of previous mitigative actions (see section 6.1.14), if this site is identified as necessary for restoration. The success of these remediation measures will be effective reduction of selenium to levels deemed acceptable for rearing of razorback sucker and bonytail.

3. Comprehensive Larval Drift Report.

A comprehensive larval drift study should be conducted to identify drift patterns and decay rate of drifting larvae downstream from a spawning site. This drift study should include a comprehensive geomorphology assessment of key floodplain sites to determine best strategies for levee breaches. Key floodplain sites include Thunder Ranch, Stewart Lake, Bonanza Bridge, The Stirrup, Baeser Bend, Above Brennan, Johnson Bottom, Leota Ponds, and Old Charlie Wash−Main. Evaluation of drift should prioritize Thunder Ranch and Stewart Lake, and initial success of this action should be gaged on successful documented larval entrainment at the two priority floodplain sites.

4. Comprehensive Growth/Survival Report.

Various studies have been conducted on growth and survival of hatchery-reared razorback sucker and bonytail at several floodplain sites (see section 6.2 for description of studies by site). These studies have involved primarily caged fish introduced at different sizes and under different densities of nonnative fishes. This information should be assimilated and evaluated to determine further need for these studies and to identify a specific strategy for use of hatchery fish to augment the wild populations. Growth and survival of hatchery razorback sucker and bonytail should be evaluated at the Thunder Ranch floodplain following levee breaches. Growth and survival of hatchery fish should also be evaluated at Stewart Lake if a coordinated management program is developed with UDWR, Reclamation, and the Service. Effects of selenium on endangered fishes should be documented. The success of this action should be gaged by development of a strategy for releasing hatchery-reared fish into the wild that will result in recruitment to the wild population. Information from this assessment will bear directly on growth and survival of wild larvae entrained in floodplains.

5. Coordination with UDWR, Reclamation, and the Service on management of Stewart Lake.

The Recovery Program should coordinate management of Stewart Lake with UDWR, Reclamation, and the Service. Coordination was initiated in 2001 and will continue into 2004. Management of Stewart Lake as a nursery for razorback sucker is feasible under the current water management strategy, but extending the inundation period will allow entrained razorback sucker to reach greater size before escapement and increase their chances of survival in the mainstem. Coordinated management of Stewart Lake should balance the mission of the waterfowl management area, suitable selenium remediation, and the needs of endangered fishes.

6. Coordination with Ouray National Wildlife Refuge on management of key refuge floodplains.

The Recovery Program should coordinate management of Leota Ponds and Johnson Bottom as nursery habitat for razorback sucker, and possibly bonytail. Collectively, these floodplains represent about 1,162 acres of inundation at 18,600 cfs. Existing levee breaches allow these floodplains to become inundated at about 13,000 cfs, and internal dike breaches allow for inundation of multiple internal units or ponds. These sites currently function as nurseries, but do not drain well. Specific strategies for these sites would need to be identified and coordinated with ONWR through a Summary Action Plan I to insure that these actions do not negatively affect refuge goals and objectives. The success of this action is coordinated management of these sites and documented entrainment and production of razorback sucker to the wild population.

7. Coordination with ONWR on management of additional refuge floodplains.

The Recovery Program may coordinate management of other refuge floodplains, if necessary. Sheppard Bottom, Wyasket Lake, and Old Charlie Wash−Diked are identified as floodplain sites for possible restoration, if other management actions do not provide sufficient benefit to recovery of razorback sucker. Sheppard Bottom and Wyasket Lake are large shallow depressions with large potential floodable area, but may require excavation to retain water for periods of time. Old Charlie Wash−Diked is part of the Old Charlie Wash site and may also require excavation for water retention and draining. Specific strategies for these sites would need to be identified and coordinated with ONWR through a Summary Action Plan II to insure that these actions do not negatively affect refuge goals and objectives. The success of this action is successful coordinated management of these sites and documented entrainment and production of razorback sucker to the wild population.

8. Easement for access and management of Sportsman's Lake.

The Recovery Program may execute a easement for access and management of Sportsman's Lake, depending on the need to restore this site. That need will be determined following evaluation of other prior management actions and their effectiveness to species recovery.

7.4.2 Achievement Of Larval Entrainment And Fish Escapement

The second set of success criteria is based on the relative contribution of each floodplain site to average annual recruitment for razorback sucker of 30% (i.e., 5,800 x 0.30 = 1,740). These criteria are based on model simulations with an adult population of 5,800, a single spawning site, and 14 floodplain sites entraining larvae and successfully rearing fish (Table 7-4). At 80, 90, and 95% mile-to-mile larval survival, estimated survival rate necessary from larvae to adult is less than 1.0%; i.e., 0.885%, 0.292%, and 0.138%, respectively. The IMC and Richen/Slaugh floodplains are not included in the model because of the terraced nature of these sites.

Model simulations indicate that the two sites nearest the spawning bar (i.e., Thunder Ranch and Stewart Lake) could account for 90% of necessary annual recruitment (i.e., 1,269+299=1,568; 1,568/1,740=0.90). Assuming that a single spawning bar exists, it becomes evident from Table 7-4 that the relative potential of floodplain sites to total recruitment is greatly influenced by distance downstream from the source of emerging larvae. Nevertheless, the importance of other floodplain sites should not be discounted because an expansion of the razorback sucker population will likely result in additional spawning sites closer to other floodplain sites identified in this Plan.

Table 7-4. Estimated larval entrainment at 80, 90, and 95% mile-to-mile survival rate, and numbers of adults necessary to be produced at each of 14 floodplain sites to achieve 30% recruitment (i.e., 1,740 adults annually). RM=river mile distance upstream from the Colorado River confluence; MFSB=miles from spawning bar; necessary survival rate from larvae to adult is 0.885%, 0.292%, and 0.138%, at 80, 90, and 95% mile-to-mile survival, respectively. Estimates were derived from the Floodplain Model (Valdez 2004).

Floodplain Site	RM	MFSB	80%	0.00885	90%	0.00292	95%	0.00138
Spawning Bar	310	0						
Thunder Ranch	306	5	143,392	1269	290,696	849	402,092	554
Stewart Lake	300	11	33,830	299	139,039	406	266,017	366
Sportsman Drain	297	14	15,589	138	91,223	266	205,269	283
Bonanza Bridge	290	21	2,942	26	39,269	115	129,012	178
Horseshoe Bend	284	27	694	6	18,782	55	85,352	118
The Stirrup	275	36	84	1	6,549	19	48,414	67
Baeser Bend	273	38	48	0	4,774	14	39,324	54
Above-Brennan	266	45	9	0	2,055	6	24,715	34
Johnson Bottom	264	47	5	0	1,498	4	20,075	28
Leota Ponds	259	52	2	0	796	2	13,980	19
Wyasket Lake	256	55	1	0	522	2	10,788	15
Sheppard Bottom	253	58	0	0	343	1	8,324	11
Old Charlie Wash	251	60	0	0	250	1	6,761	9
Lamb Property	241	70	0	0	78	0	3,643	5
Total Larvae Entrained and Surviving:			196,597		595,875		1,263,768	
Adults Produced:				1740		1740		1740

7.5 Uncertainties, Risks, and Contingencies

There are inherent uncertainties and risks associated with any plan of action. It is prudent to understand these uncertainties and to establish research needs to fill information gaps, as well as contingencies to accommodate errors in predicted outcomes. The following are uncertainties and risks associated with this Plan, and possible contingencies. These contingencies constitute alternative management actions that may be necessary to achieve species recovery. Other contingencies not described in this Plan may be identified as knowledge is gained from implementation and evaluation of management actions. Properly designed studies, structural features, and management strategies will inevitably increase the probability of success and minimize the need for contingencies.

1. Effectiveness and alternatives for "reset theory".

The fundamental principle behind this Plan is the "reset theory" in which floodplains are allowed to inundate and desiccate on a 12 or 24-month cycle to provide productive habitats for maximum growth of razorback sucker with escapement to the river, and to periodically kill nonnative fishes that are entrained in these habitats. This floodplain management strategy has not been fully tested and evaluated. Elements of this strategy have shown to be effective (e.g., enhanced floodplain connection with levee modification, high fish growth in floodplains, survival in high densities of nonnative fishes), but others continue to be evaluated (e.g., larval entrainment, best survival, minimization of nonnative effects from periodic desiccation). There are a number of uncertainties and inherent risks in managing floodplains to hold fish for 12 or 24 months, including early departure by fish, desiccation of the floodplain during the 12 or 24 month period, failure of the floodplain to reconnect because of extended low river flows, disease outbreaks in floodplains, and predation and competition from nonnative fishes. The Recovery Program has gained considerable understanding of floodplain functions and values and best management strategies from applied experience, particularly since about 1992. Continued and ongoing evaluation of various elements of this strategy are vital to understanding successes and failures and making necessary adjustments to insure overall success.

If evidence from monitoring indicates that this approach will not achieve a self-sustaining population of razorback sucker or bonytail, as judged by the Recovery Program, an alternative or modification of the strategy may need to be implemented as a contingency. Some aspects of the "floodplain repatriation" strategy being used in the Lower Colorado River Basin may apply. Floodplains in the lower basin are isolated from the river and desiccated or chemically treated to completely eliminate nonnative fishes. Razorback sucker or bonytail are stocked and held for 24 months, then manually released to the river. This is a highly managed system that requires ongoing investment in resources and is not consistent with the concepts of long-term species recovery and population self-sustainability. However, it may be possible to combine this strategy of contained rearing of fish to initiate the population, then allow the "reset theory" to function within the framework of floodplain restoration and flow regulation.

2. Entrainment of wild razorback sucker larvae.

Entrainment of wild razorback sucker larvae at key floodplain sites is critical to the success of this plan and to species recovery. Drift characteristics and entrainment of larval razorback sucker are not well understood. Larvae may not become entrained in sufficient numbers at key managed floodplains, and reconfiguration of floodplain levees, inlets, and outlets may be necessary, including installation of water control structures. Entrainment is also a function of river flow timing, and it may be necessary to evaluate and possibly revise Green River flow recommendations, specifically the timing of Flaming Gorge Dam releases to Yampa River peaks, in order to maximize entrainment. Entrainment is expected to be a resolvable issue.

3. Growth and survival over a 12 to 24-month period.

High rates of growth are consistently demonstrated in floodplains by most fish species. Of greatest concern is whether a fish can quickly reach sufficient size in an available floodplain to minimize the risk of predation in the floodplain or the main river channel. The greater uncertainty is whether sufficient numbers of razorback sucker or bonytail can survive in floodplains to recruit at a rate that equals or exceeds adult mortality. It may be necessary to install inlet and outlet gates to regulate inflow and outflow, water level in the floodplain, and fish escapement. Water control will also allow for a periodic influx of fresh water into floodplains to minimize disease outbreaks and insure water quality.

4. Loss of fish in short-term floodplains.

Some floodplains are small and/or shallow and do not hold water year-around. Fish that become stranded in these floodplains will die from poor water quality or desiccation. Hence, fish that use these short-term floodplains must escape to the river as flows recede. However, fish that escape the floodplain at a small size (i.e., <90 mm TL) will likely have low survival in the mainstem. Short-term floodplains may have little value as nurseries, but isolating these from the river is not recommended at this time because these sites may remain flooded during wet years and successfully produce fish. These sites may also be used transiently by large juvenile and adult razorback sucker, bonytail, and Colorado pikeminnow during spring runoff.

5. Reduction in nonnative fish effect.

Nonnative fish from the Green River will gain access to floodplains during inundation, and some will produce young that could escape back to the river and bolster overall nonnative fish populations. The strategy of cyclic inundation/desiccation of these floodplains will reduce this effect. Also, benefits gained from possible razorback sucker survival and from providing habitat for transient adult Colorado pikeminnow and possibly razorback sucker and bonytail during runoff outweigh the risk of enhanced nonnative fish production. Currently, it is believed that benefits gained from possible razorback sucker survival in wet years and from providing access to transient juveniles and adults during runoff outweigh the risk of enhanced nonnative fish production. If it is determined that this floodplain management strategy is serving to bolster nonnative fish populations, elements of the "floodplain repatriation" strategy may need to be implemented.

6. Erosion of levee modifications.

Levee breaches and possibly inlet and outlet control gates are identified as important structural components of some floodplains to provide control of inundation, desiccation, and escapement of fish. These breaches and control gates are susceptible to erosion and damage by high river flows, and should be engineered to account for this risk. Such features as gated canal inlets/outlets (instead of structures on the exposed face of levees), and lowered portions of levees (e.g., "Texas crossings") to relieve pressure of high flows should be considered. Breaches and gates should not include fish screens or kettles that may impede water flow and are more likely to erode. Water control gates are a contingency in case natural inundation and draining is ineffective.

7. Effect of selenium levels on fish health.

High selenium concentration has been identified at Thunder Ranch and Stewart Lake. These sites have the potential to naturally produce large numbers of recruitable size razorback sucker and bonytail, but potential detrimental effects of selenium on fish health and necessary remediation strategies may negate this benefit. Studies of selenium effects on the Colorado River endangered fish species are largely inconclusive, and this issue should continue to be evaluated as part of ongoing Recovery Program water quality monitoring, as specified in species recovery goals.

High selenium concentration at Thunder Ranch is primarily from agricultural runoff and occurs principally at springs and seeps that can be piped away from the floodplain. Selenium at Stewart Lake has been identified as a concern for several years, and Reclamation and the Service have implemented measures to reduce concentrations and remediate effects. This floodplain management plan identifies the need to coordinate with UDWR, Reclamation and the Service to manage Stewart Lake to benefit razorback sucker and not negatively impact waterfowl management, including selenium remediation. If suitable remediation is not possible, it will be necessary for the Recovery Program to re-focus restoration activities on floodplains within the ONWR as part of Phase II of this Plan (i.e., Leota Ponds and Johnson Bottom). These floodplains are located further downstream from the razorback sucker spawning site and may not provide the immediate benefits of floodplain sites closer to the spawning bar. These sites may require further structural levee modifications or basin excavations, all in coordination with ONWR. Stewart Lake has the necessary structural components and design for floodplain management at a minimal cost, and having to find an alternative site would likely be more costly.

7.6 Research Needs

The following research needs are identified to address uncertainties and to fill information gaps necessary for achievement of this Plan. These research needs are not described in detail or listed in order of priority to allow flexibility for implementation, depending on success of previous actions and available funding.

1. Evaluate effectiveness of “reset theory”.

Key floodplains should be evaluated for effectiveness of restoration by the Recovery Program. Evaluation should include effectiveness of connection with the river, larval entrainment, growth and survival of fish, escapement to the river, and recruitment to the wild adult population, as documented by increased numbers of adults and marked fish returning to the spawning bar. This ongoing evaluation should be part of an adaptive management approach to make changes or adjustments in the floodplain management strategy.

2. Describe larval drift and entrainment.

Characteristics of downstream drift and larval entrainment should be described to assess the effectiveness of key floodplain sites, and to guide best strategies for levee modification and construction. This evaluation should be part of the Comprehensive Larval Drift Report. Existing information should be assimilated to assess geomorphic and hydrologic characteristics of the river channel and key floodplains in order to determine the best strategy for breaching levees separating the main channel from the floodplain to achieve maximum flooding and larval entrainment. Key floodplain sites include Thunder Ranch, Stewart Lake, Bonanza Bridge, the Stirrup, Baeser Bend, Above Brennan, Johnson Bottom, Leota Bottom, and Old Charlie Wash-Main.

3. Assess growth and survival.

A Comprehensive Growth/Survival Report should be assembled to integrate, synthesize, and interpret past fish growth and survival studies. This report should assess the state of knowledge, identify essential information gaps, guide additional research, and recommend best strategies for releasing hatchery-reared fish.

4. Evaluate effects of nonnative fishes.

It is known that nonnative fishes generally have a negative effect on native species recovery. It is also known that removal strategies for small-bodied nonnative fishes in the large Colorado River ecosystem have limited success, short of total isolation and chemical treatment of confined habitats. This floodplain management plan is based on the fundamental hypothesis that razorback sucker recovery can be assisted with restoration of floodplain habitats and flow regulation in the presence of a large and diverse community of nonnative fish species. Future research and evaluation of the management actions identified in this Plan should focus on this fundamental strategy; i.e., like Colorado pikeminnow and humpback chub, recovery of razorback sucker and possibly bonytail can be achieved in the presence of nonnative species, given suitable habitat conditions and river flows.

8.0 RECOMMENDATIONS

The following recommendations identify actions that should either be implemented immediately or should be prioritized for implementation. These recommendations are intended to provide direct and immediate guidance for initiating implementation of this floodplain management plan. These actions are not ordered by priority.

1. **Suspend further acquisition of private property easements in the Green River Subbasin.**

Activities and expenditures by the Recovery Program for further acquisition of private property easements in the Green River Subbasin should be suspended. Most available private property easements have been negotiated and further acquisition of easements may not be necessary. Floodplain area currently accessible to the Recovery Program through negotiated easements and coordination with State and Federal agencies is estimated as sufficient habitat for recovery of razorback sucker. Further acquisition of easements should be continued only if management actions are ineffective or if floodplain depression area is insufficient through specified management actions.

2. **Implement restoration and management of Thunder Ranch floodplain.**

The first priority of this Plan is restoration and management of the floodplains at Thunder Ranch. This floodplain is only 5 miles from the razorback sucker spawning bar and can potentially entrain large numbers of wild-produced razorback sucker larvae.

3. **Coordinate management of Stewart Lake with Utah Division of Wildlife Resources, Bureau of Reclamation, and U.S. Fish and Wildlife Service.**

The second priority of this Plan is coordinated management of Stewart Lake, which is managed by the UDWR primarily for waterfowl. Reclamation and the Service have implemented remediation measures for selenium, which has been identified as a risk to waterfowl and fish health. Stewart Lake currently has the structural components (i.e., inlet/outlet control gates, lowered portions of levee for flooding, trenched depression for draining) for management as a 12-month depression floodplain, and the Recovery Program should coordinate with UDWR, Reclamation, and the Service to manage the floodplain to benefit the razorback sucker and not negatively impact waterfowl management and necessary selenium remediation.

4. **Coordinate floodplain restoration and management with Ouray National Wildlife Refuge.**

The majority of potential floodplain depression habitat is located in the ONWR. The Recovery Program should initiate coordination and establish a partnership, as necessary, with

ONWR to manage key floodplains to benefit the endangered fishes and not negatively impact the goals and objectives of the ONWR Comprehensive Conservation Plan (2000). Two Summary Actions Plans are identified in this Plan to insure that the fundamental principals and actions of floodplain restoration are consistent with Recovery Program needs and ONWR goals and objectives. Summary Action Plan I provides an overview of necessary management actions for Leota Ponds and Johnson Bottom. If necessary, Summary Action Plan II would be developed to provide an overview of necessary management actions for Sheppard Bottom, Wyasket Lake, and Old Charlie Wash−Diked. These action plans are intended to provide a summary of proposed actions and strategies and not comprehensive and detailed engineering designs or study plans.

5. Continue to monitor, evaluate, and manage restored floodplains.

The Recovery Program has initiated restoration on eight sites: Bonanza Bridge, Horseshoe Bend, The Stirrup, Baeser Bend, Above Brennan, Johnson Bottom, Leota Ponds, and Old Charlie Wash. These sites should be monitored, evaluated, and managed for effectiveness as habitat for all life stages of razorback sucker and bonytail.

6. Continue stocking of hatchery razorback sucker and bonytail.

Release of hatchery razorback sucker and bonytail is vital to species recovery. These fish augment sparse wild populations and provide the foundation for a self-sustaining population. Surplus fish are used for studies and experimentation of growth and survival. Stocking also provides fish in the wild to better assess best management strategies for floodplains. Biologists should continue to monitor distribution and behavior of razorback sucker to evaluate and identify additional and potential spawning sites. Potential spawning sites should be identified and further investigated.

7. Assimilate and synthesize results of fish growth and survival in floodplains.

Studies of growth and survival of hatchery razorback sucker and bonytail have been on-going since 1996. More recent and on-going studies address pertinent issues of best size at stocking and survival under varying levels of nonnative fish densities. A Comprehensive Growth/Survival Report should be assembled to integrate, synthesize, and interpret past fish growth and survival studies. This report should assess the state of knowledge, identify essential information gaps, guide additional research, and recommend best strategies for releasing hatchery-reared fish.

8. Evaluate characteristics of water and larval entrainment.

A Comprehensive Larval Drift Report should be developed to assess geomorphic and hydrologic characteristics of water and larval entrainment at key floodplain sites. Existing information should be assimilated to determine the best strategy for breaching levees to achieve maximum flooding and larval entrainment. Known characteristics of larval drift should also be described, and additional necessary research and structural modifications to key floodplain sites identified and recommended for consideration by the Recovery Program.

9. Use existing programs to monitor response by razorback sucker and bonytail.

The Recovery Program should use existing programs, as much as possible, to monitor population response by razorback sucker and bonytail to floodplain management actions. Continued release of hatchery fish and restoration of floodplains should lead to successful reproduction and recruitment that should be detected by on-going sampling programs. Various sizes of razorback sucker and bonytail should be captured during sampling for population estimates with electrofishing for Colorado pikeminnow and trammel nets and hoop nets for humpback chub. This sampling is being conducted through most of the Green River Subbasin, and should provide sufficient geographic coverage and sampling intensity for detecting increased numbers of razorback sucker and bonytail. The Recovery Program may choose to implement in the future a more detailed sampling program for population estimates to document self-sustainability. Monitoring for downlisting and delisting will be implemented after self-sustained populations are established, as specified in species recovery goals.

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APPENDIX A: Tables of Floodplain Sites in the Green River Subbasin

Table A-1. The top 11 ranked bottomland habitats in the Split Mountain to Desolation Canyon Reach identified by Irving and Burdick (1995).

Site Description	River Mile	Rank
Johnson Bottom, Ouray NWR	263.0-265.0	1
Leota Pond Complex, Ouray NWR	257.0-262.0	1
Wyasket Lake, Ouray NWR	253.0-257.0	2
Sheppard Bottom, Ouray NWR	254.0-256.0	2
Old Charlie Wash (main)/Woods Bottom, Ouray NWR	249.0-252.0	2
Old Charlie Wash (diked)/Woods Bottom, Ouray NWR	249.0-250.0	2
Brennan Bottom	262.0-266.0	2
Little Stewart Lake	295.5-297.5	2
Stewart Lake	299.0-300.0	3
Ashley Creek confluence area	297.0-298.5	3
Escalante Ranch (now referred to as Thunder Ranch)	302.5-309.5	4
Meril Snow Ranch	302.0-303.0	4
Gravel Ponds at Jensen	301.0-302.0	4
Spring Hollow	295.0-296.0	4
Bonanza Bridge Area	288.5-298.0	5
Collier Draw	285.5-286.5	5
Walker Hollow	294.0-295.0	6
Alhandra Ferry Site	292.0-294.0	6
Gravel Pits	292.0-293.0	6
Mouth of Willow Creek	239.0-241.0	7
Pariette Draw	238.0-241.0	7
Downstream of Baeser Bend	269.0-272.0	8
Upstream of Brennan Bottom	267.0-269.0	8
Upstream of Brennan Bottom	266.0-267.0	8
Ouray Ute pasture land	248.0-251.0	8
Duchesne River confluence area	248.0-249.0	8
White River confluence area	248.0-249.0	8
West Branch area	243.0-247.0	8
Tia Juana Bottom	242.0-244.0	8
Hamacker Bottom/Baeser Bend	271.0-274.0	9
The Stirrup	274.0-277.0	10
Horseshoe Bend	277.0-284.0	11

Table A-2. Ranked bottomland habitats in the Labyrinth and Stillwater Canyons Reach identified by Irving and Burdick (1995).

Site Description	River Mile	Rank
Hey Joe Canyon	74.5-76.0	17
Hey Joe Canyon–Spring Canyon	74.0-75.0	17
Spring Canyon Point	69.5-74.0	17
Bowknot Bend	62.0-70.0	17
Twomile Canyon–Deadman Point	60.0-62.0	17
Deadman Point–Horseshoe Canyon	59.0-60.0	17
Downstream of Horseshoe Canyon	58.0-59.0	17
Cottonwood Bottom	55.0-56.5	17
Cottonwood–Mineral Bottoms	54.0-55.0	17
Mineral–Tidwell Bottoms	53.0-54.0	17
Tidwell Bottom	51.0-52.5	17
Horsethief Bottom	50.0-51.5	17
Woodruff Bottom	49.0-50.0	17
Point Bottom	47.5-49.5	17
Saddle Horse Bottom	45.5-47.5	17
Horsethief Canyon	45.0-46.0	17
Horsethief–Upheaval Bottom	44.0-45.0	17
Upheaval Bottom/Canyon	43.5-44.5	17
Hardscrabble Bottom	42.5-43.5	17
Hardscrabbble–Fort Bottoms	38.5-42.5	17
Potato Bottom	35.5-38.0	17
Potato–Beaver Bottoms	34.5-35.5	17
Beaver–Queen Ann Bottoms	33.5-34.5	17
Queen Ann Bottom	33.0-34.0	17
Queen Ann–Anderson Bottom	32.0-33.0	17
Anderson Bottom	30.0-31.5	17
Unknown and Valentine Bottoms	29.0-32.0	17
Valentine Bottom	27.0-29.0	17
Stillwater Canyon–Sphinx	26.0-28.5	17
Downstream Valentine Bottom	25.5-26.5	17
Tuxedo Bottom–Turks Head	24.0-25.5	17
Deadhorse Canyon confluence	19.5-24.0	17

Table A-2. (Continued)

Downstream Deadhorse Canyon	18.5-20.0	17
Deadhorse–Horse Canyons	17.0-19.0	17
Horse Canyon	16.0-17.0	17
Downstream of Horse Canyon	13.5-14.0	17
Horse–Jasper Canyons	12.5-13.5	17
Jasper Canyon	10.5-12.5	17
Jasper Canyon–Short Canyon	5.0-8.0	17
Short Canyon–Colorado River	2.0-3.5	17
Upstream of Colorado River	1.0-2.0	17
Near Colorado River confluence	0.5-1.5	17
Colorado River confluence	0.0-0.5	17

Table A-3. Ranked bottomland habitats in the Gray Canyon to Labyrinth Canyon Reach identified by Irving and Burdick (1995).

Site Description	River Mile	Rank
Willow Bend/Tusher Rapid	128.5-129.5	16
Short Canyon/Rapids	131.5-132.5	17
Little Grand Wash	114.5-155.5	17
Downstream of Grand Wash	113.0-114.0	17
Fivemile Wash/Little Valley	111.0-112.0	17
Downstream of Ninemile Wash	109.0-111.0	17
Anvil Bottom	101.5-102.5	17
Upstream of San Rafael River	98.0-99.0	17
San Rafael River confluence	96.5-97.5	17
White and Red Wash	95.0-96.5	17
Between Red Wash–Bull Bottom	94.0-95.5	17
Bull Bottom–Labyrinth Canyon	92.0-93.0	17
Labyrinth Canyon confluence	91.5-92.5	17
Three Canyon/Trin-Alcove Bend	88.5-91.5	17
Junes Bottom	87.0-88.0	17
Junes Bottom–Bull Hollow	85.0-86.0	17
Bull Hollow	84.0-85.0	17
Bull Hollow–Tenmile Canyon	81.0-83.0	17
Tenmile Canyon/Bottom	79.0-82.0	17
Keg Springs Canyon	75.0-78.5	17
Upriver of Green River, Utah	121.5-125.5	18

APPENDIX B: Floodplain Model Simulations

B-1. Simulation #1: Number of Larvae Entrained and Potential Recruitment With and Without Thunder Ranch

This model simulation illustrates the importance of certain floodplains, especially those located nearest the spawning bar. The Recovery Program is in the process of trying to acquire Thunder Ranch, a floodplain site located about 5 miles downstream of the known spawning bar of razorback sucker. The model starts with 5,469,955 larvae escaping the spawning bar. Assuming that 90% of the larvae remain drifting in the river at the end of each river mile (i.e., 10% die and/or are entrained along the shoreline), the number of larvae entrained is 76% greater with access to Thunder Ranch (Table B-1). If 0.5% of the entrained larvae survive to recruit as adults, the number of adults produced is 2,979 and 1,695, with and without Thunder Ranch, respectively for a difference of 1,284 adults recruited to the population.

Table B-1. Number of larval razorback sucker potentially entrained with and without Thunder Ranch in each of the floodplain sites in the Split Mountain to Desolation Canyon reach of the Green River. Estimated entrainment is based on the Floodplain Model with the following assumptions: number of adults = 5,800; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; entrainment at each floodplain site = 10%; mile-to-mile survival of drifting larvae = 90%; number of larvae escaping the spawning bar = 5,469,955.

Floodplain	River Mile	Miles Below Spawn Bar	%Entrainment	No. Entrained Without Thunder Ranch	No. Entrained With Thunder Ranch
Spawning Bar	311	0			
Thunder Ranch	306	5	10	0	290,696
Stewart Lake	300	11	10	154,488	139,039
Sportsman Lake	297	14	10	101,359	91,223
Bonanza Bridge	290	21	10	43,632	39,269
Horseshoe Bend	284	27	10	20,869	18,782
The Stirrup	275	36	10	7,277	6,549
Baeser Bend	273	38	10	5,305	4,774
Above-Brennan	266	45	10	2,283	2,055
Johnson Bottom	264	47	10	1,665	1,498
Leota Bottom	259	52	10	885	796
Wyasket	256	55	10	580	522
Sheppard	253	58	10	381	343
Old Charlie Wash	251	60	10	278	250
Lamb	241	70	10	87	78
Total Larvae Entrained:				339,088	595,875

B-2. Simulation #2: Number of Larvae Entrained Based on Percent Survival From One Mile To The Next

The Floodplain Model assumes a 10% entrainment rate at each of the 16 identified floodplain sites. The numbers of larvae entrained at 80%, 90%, and 95% mile-to-mile survival rates are 196,597; 595,875; and 1,263,768, respectively (Table B-2, Figure B-1). An increase in 10% survival (i.e., 80% to 90%) results in a 203% increase in potential larval entrainment, and a 15% increase in survival (i.e., 80% to 95%) results in a 543% increase in potential entrainment.

Proximity of floodplain sites to a spawning bar is vital for maximum larval entrainment. Floodplain sites closest to the spawning bar have the greatest potential to entrain the largest numbers of larvae. The model shows the significance of numbers of drifting larvae surviving from one mile to the next. If 80% of 5,469,955 drifting larvae survive from one mile to the next, the model estimates that only 1,048 larvae are left in the river 35 miles below the spawning bar (these numbers are from the Drift Submodel of the Floodplain Model and are not shown in any tables in this plan). At 90% mile-to-mile survival, only about 72,766 (1.33%) of the larvae emerging from the spawning bar remain in the river channel 35 miles from the spawning bar; and at 95% survival, about 509,620 (9.32%) remain. Hence, the numbers of larval razorback sucker that are potentially entrained at the Leota Bottom site (52 miles downstream from the spawning bar) at for 80, 90, and 95% mile-to-mile survival are 2; 796; and 13,980, respectively. Mile-to-mile survival also has a significant effect on total numbers of larvae entrained in existing floodplain sites. An increase of 10% survival rate, from 80% to 90%, translates to a 303% increase in total larval entrainment (i.e., 196,597 to 595,875), and a 15% increase, from 80% to 95%, translates to a 643% increase in total larval entrainment (i.e., 196,597 to 1,263,768).

Table B-2. Number of larval razorback sucker potentially entrained in each of 14 floodplain sites in the Split Mountain to Desolation Canyon reach of the Green River, based on 80%, 90%, and 95% survival of drifting larvae from one mile to the next. Estimated entrainment is based on the Floodplain Model with the following assumptions: number of adults = 5,800; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; entrainment at each floodplain site = 10%; number of larvae escaping the spawning bar = 5,469,955.

Floodplain Site	River Mile	Miles Below Spawning Bar	Number of Larvae Entrained Based on Percent Survival From One Mile To The Next		
			80%	90%	95%
Spawning Bar	310	0	Larval Escapement = 5,469,955		
Thunder Ranch	306	5	143,392	290,696	402,092
Stewart Lake	300	11	33,830	139,039	266,017
Sportsman Drain	297	14	15,589	91,223	205,269
Bonanza Bridge	290	21	2,942	39,269	129,012
Horseshoe Bend	284	27	694	18,782	85,352
The Stirrup	275	36	84	6,549	48,414
Baeser Bend	273	38	48	4,774	39,324
Above-Brennan	266	45	9	2,055	24,715
Johnson Bottom	264	47	5	1,498	20,075
Leota Bottom	259	52	2	796	13,980
Wyasket	256	55	1	522	10,788
Sheppard	253	58	0	343	8,324
Old Charlie Wash	251	60	0	250	6,761
Lamb Property	241	70	0	78	3,643
Total Larvae Entrained:			196,597	595,875	1,263,768

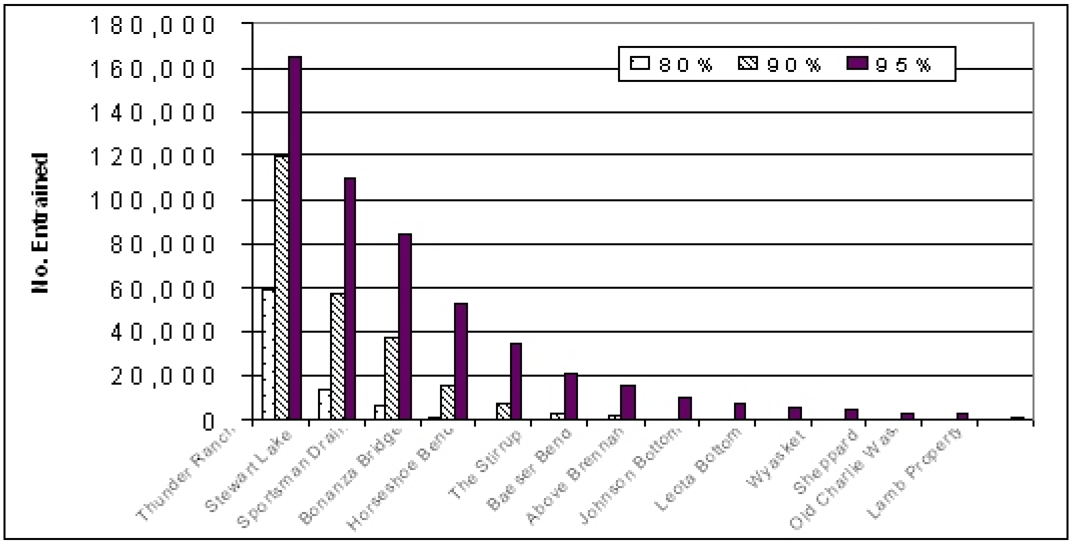

Figure B-1. Number of larval razorback sucker potentially entrained in each of 14 floodplain sites in the Split Mountain to Desolation Canyon reach of the Green River, based on 80%, 90%, and 95% survival of drifting larvae from one mile to the next. Estimated entrainment is based on the Floodplain Model with the following assumptions: number of adults = 5,800; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; entrainment at each floodplain site = 10%; number of larvae escaping the spawning bar = 5,469,955.

B-3. Simulation #3: Number of Larvae Entrained Proportional To Potential Floodplain Area

If it is assumed that larval entrainment is proportional to floodplain area (i.e., larger floodplains entrain more water and thus greater numbers of larvae), the average potential floodplain area of the 16 sites is 392 acres (Table 3). By setting the Floodplain Model to assume 10% entrainment for 392 acres, entrainment by site and total entrainment can be estimated by proportioning percent larval entrainment by area for all floodplain sites (e.g., Thunder Ranch at 750 acres divided by 392 = 1.91 x 10% = 19.14%; Table B-3; Figure B-2). Model simulations for 80, 90, and 95% mile-to-mile survival show the same decreasing entrainment pattern with downstream distance, but a greater number of larvae entrained in the larger floodplain sites; i.e., Thunder Ranch, Stewart Lake, Horseshoe Bend, Baeser Bend, and Leota Bottom. This increased entrainment rate with inflow increases potential entrainment by 407% at the downstream-most sites, such as Leota Bottom, from 13,980 to 56,914 larvae at 95% mile-to-mile survival.

Table B-3. Number of larval razorback sucker potentially entrained in each of 14 floodplain sites in the Split Mountain to Desolation Canyon reach of the Green River, based on entrainment rate proportional to potential floodplain area, and on 80%, 90%, and 95% survival of drifting larvae from one mile to the next. Estimated entrainment is based on the Floodplain Model with the following assumptions: number of adults = 5,800; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; entrainment at each floodplain site = proportional to potential area; number of larvae escaping the spawning bar = 5,469,955.

Floodplain Site	Miles Below Spawning Bar	Percent Entrainment Proportional To Floodplain Area	Number of Larvae Entrained		
			80%	90%	95%
Spawning Bar	0		Larval Escapement = 5,469,955		
Thunder Ranch	5	19.1	273,878	555,229	767,996
Stewart Lake	11	16.9	51,392	211,217	404,112
Sportsman Drain	14	6.7	8,669	50,728	114,146
Bonanza Bridge	21	1.3	329	4,392	14,430
Horseshoe Bend	27	6.1	400	10,811	49,127
The Stirrup	36	0.3	2	193	1,430
Baeser Bend	38	14.0	74	7,289	60,040
Above-Brennan	45	1.8	2	385	4,636
Johnson Bottom	47	6.6	4	1,124	15,065
Leota Bottom	52	34.5	6	3,241	56,914
Wyasket	55	22.7	1	1,018	21,030
Sheppard	58	18.4	0	465	11,297
Old Charlie Wash	60	7.7	0	129	3,482
Lamb Property	70	4.0	0	22	1,000
		Total Larvae Entrained:	334,758	846,244	1,524,706

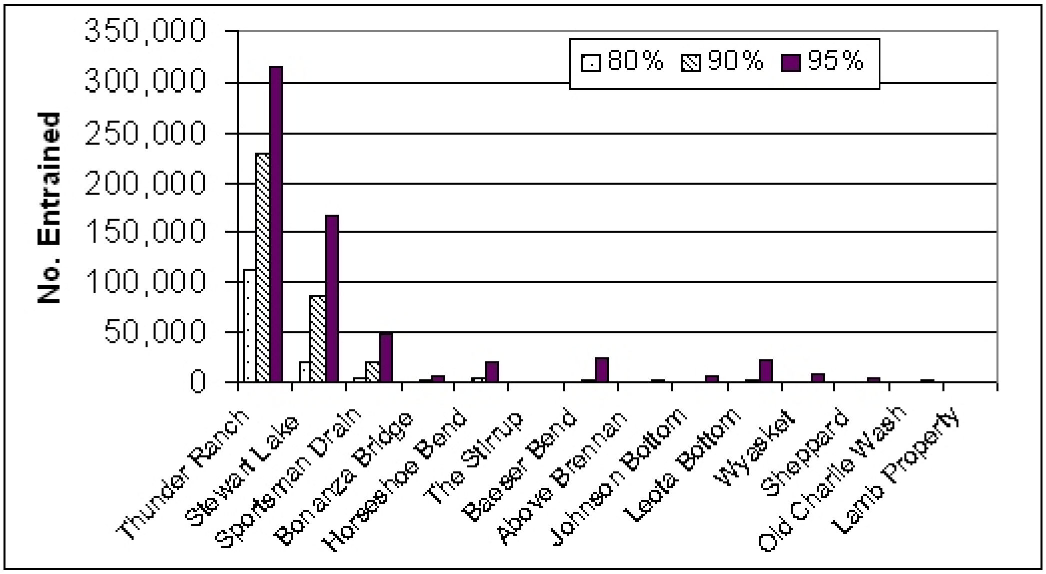

Figure B-2. Number of larval razorback sucker potentially entrained in each of 14 floodplain sites in the Split Mountain to Desolation Canyon reach of the Green River, based on entrainment rate proportional to potential floodplain area, and on 80%, 90%, and 95% survival of drifting larvae from one mile to the next. Estimated entrainment is based on the Floodplain Model with the following assumptions: number of adults = 5,800; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; entrainment at each floodplain site = proportional to potential area; number of larvae escaping the spawning bar = 5,469,955.

B-4. Simulation #4: Number of Larvae Entrained Based On One Or Two Spawning Bars

The Floodplain Model was run with the same set of parameters as in Simulation #1, except that a second spawning site was introduced at RM 160; the number of adults (5,800) was equally divided at 2,900 adults for each of the two spawning sites. There is currently a large gravel/ cobble bar at this location that could be used for spawning by razorback sucker. Dividing larval production into two spawning sites (2,734,978 emerging larvae at each) rather than one site with 5,469,955 larvae, increased potential larval entrainment by 15% (196,597 to 225,968), 11% (595,875 to 672,264), and 7% (1,263,768 to 1,362,857) for 80, 90, and 95% mile-to-mile survival (Table B-4; Figure B-3; Figure B-4). A second spawning bar also increased recruitment from 30%, 36%, and 36% to 33%, 40%, and 40% for low, moderate, and high growth rates, respectively.

Table B-4. Number of larval razorback sucker potentially entrained in each of 14 floodplain sites in the Split Mountain to Desolation Canyon reach of the Green River, based on 80%, 90%, and 95% survival of drifting larvae from one mile to the next, and a second spawning bar (2 S Bars) at RM 160. Estimated entrainment is based on the Floodplain Model with the following assumptions: number of adults at one spawning bar = 5,800 or number at each of two spawning bars = 2,900; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; entrainment at each floodplain site = 10%; number of larvae escaping from one spawning bar = 5,469,955; number escaping each of two spawning bars = 2,734,978.

Floodplain Site	River Mile	Miles Below Spawning Bar	Number of Larvae Entrained Based on Percent Survival From One Mile To The Next					
			80%		90%		95%	
			1 S Bar	2 S Bars	1 S Bar	2 S Bars	1 S Bar	2 S Bars
Spawning Bar	311	0	Larval Escapement = 2,734,978 for 2 Bars; 5,469,955 for 1 Bar					
Thunder Ranch	306	5	143,392	71,696	290,696	145,348	402,092	201,046
Stewart Lake	300	11	33,830	16,915	139,039	69,519	266,017	133,009
Sportsman Drain	297	14	15,589	7,795	91,223	45,612	205,269	102,634
Bonanza Bridge	290	21	2,942	1,471	39,269	19,634	129,012	64,506
Horseshoe Bend	284	27	694	347	18,782	9,391	85,352	42,676
Assumed Spawning Bar			Larval Escapement = 2,734,978 for 2 Bars					
The Stirrup	275	36	84	71,738	6,549	148,622	48,414	225,253
Baeser Bend	273	38	48	41,321	4,774	108,346	39,324	182,962
Above-Brennan	266	45	9	7,799	2,055	46,639	24,715	114,992
Johnson Bottom	264	47	5	4,492	1,498	34,000	20,075	93,402
Leota Bottom	259	52	2	1,325	796	18,069	13,980	65,046
Wyasket	256	55	1	610	522	11,855	10,788	50,192
Sheppard	253	58	0	281	343	7,778	8,324	38,730
Old Charlie Wash	251	60	0	162	250	5,670	6,761	31,458
Lamb Property	241	70	0	16	78	1,779	3,643	16,952
Total Larvae Entrained:			196,597	225,968	595,875	672,264	1,263,768	1,362,857

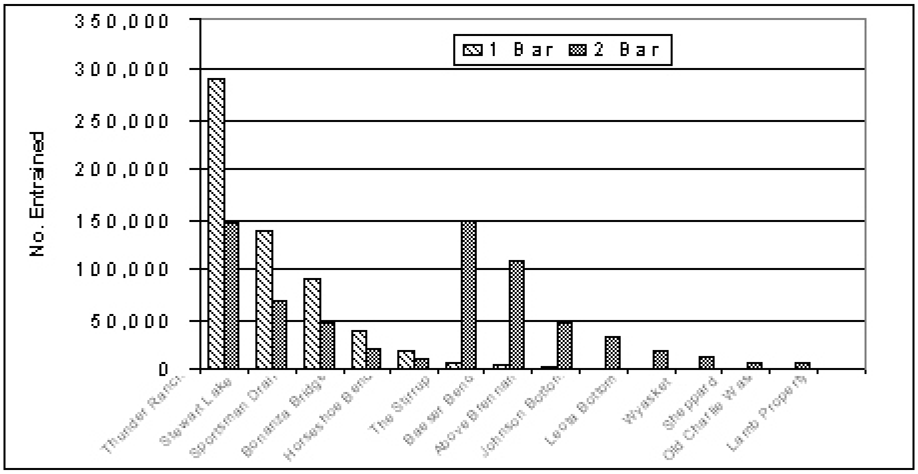

Figure B-3. Number of larval razorback sucker potentially entrained in each of 14 floodplain sites in the Split Mountain to Desolation Canyon reach of the Green River, based on 90% survival of drifting larvae from one mile to the next, and a second spawning bar (2 S Bars) at RM 160. Estimated entrainment is based on the Floodplain Model with the following assumptions: number of adults at one spawning bar = 5,800 or number at each of two spawning bars = 2,900; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; entrainment at each floodplain site = 10%; number of larvae escaping from one spawning bar = 5,469,955; number escaping each of two spawning bars = 2,734,978.

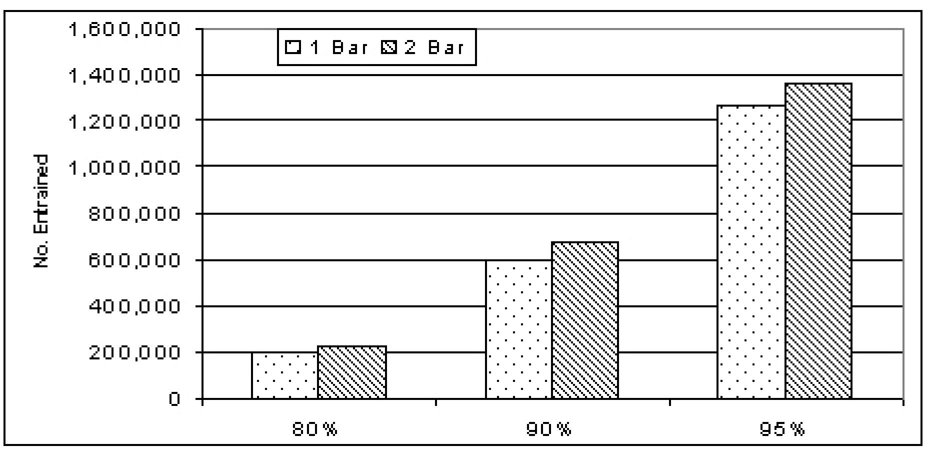

Figure B-4. Number of larval razorback sucker potentially entrained in each of 14 floodplain sites in the Split Mountain to Desolation Canyon reach of the Green River, based on 90% survival of drifting larvae from one mile to the next, and a second spawning bar (2 S Bars) at RM 160. Estimated entrainment is based on the Floodplain Model with the following assumptions: number of adults at one spawning bar = 5,800 or number at each of two spawning bars = 2,900; sex ratio = 3M:1F; average size of adults = 550 mm TL; hatching success = 10%; survival of larvae to emergence = 20%; entrainment at each floodplain site = 10%; number of larvae escaping from one spawning bar = 5,469,955; number escaping each of two spawning bars = 2,734,978.